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Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions from Motor Vehicles

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Anti-Tampering and Anti-Misfueling Programs To Reduce In-Use Emissions from Motor Vehicles

December 31, 1983

Office of Mobile Sources
Office of Air and Radiation
U. S. Environmental Protection Agency

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EPA has been collecting data since 1978 on the occurrance of tampering and misfueling to assess the magnitude of the problem. This report examines the rates of tampering and misfueling, the effects of misfueling and disablement of individual emission control components on vehicle emissions, which vehicles are equipped with each emission component, and the estimated cost of repairs. The methodology used to estimate the excess emissions caused by tampering is explained. Programs to prevent misfueling are discussed. Also included is the use of the MOBILE3 emission factor model used to calculate the adjustments to local conditions.

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1.0 INTRODUCTION

Since the 1960's when crankcase ventilation tubes on automobile engines were rerouted to prevent the venting of engine blowby gases directly into the atmosphere, automotive designers have added to and redesigned various components of the standard internal combustion engine to reduce its emissions of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx). The success of their efforts is evident in the fact that new passenger vehicles emit only a small fraction of the HC, CO, and NOx emissions of pre-controlled cars.

The full benefit of these modifications, however, is not being realized in the field. EPA studies have shown repeatedly that maladjustments, disablements, and component failures in the emission control systems of automobiles occur frequently and that the result is often emission levels many times the design (certification) standards. This means that the vehicle owners, who have paid for these emission control components when their cars were purchased, and the public, in general, have not been receiving the emission benefits of this investment because of some form of tampering, misfueling, malmaintenance or neglect. These emissions in excess of design standards are a major source of HC, CO, and NOx from mobile sources and a significant contributing factor to air pollution in urban areas.

This report will specifically address the portion of excess vehicle emissions due to tampering and misfueling. Tampering, in this report, will refer to any disablement of any component of an emission control system whether it was done deliberately, inadvertently, or through neglect. Tampering can be as simple as losing (and not replacing) a vehicle's gas cap or as deliberate as sawing off the catalytic converter. This definition does not include maladjustments which would increase emissions.

Misfueling and fuel switching in this report will mean any introduction of leaded fuel into a vehicle originally equipped with a catalytic converter. This can be done deliberately by the vehicle owner by enlarging the fuel inlet restrictor so that a leaded fuel nozzle fits, by fueling from a leaded gasoline pump with an undersized nozzle, or by using a funnel so that damaging the fuel inlet restrictor is not necessary. The majority of fuel switching currently occurs via tampered inlets. Fuel switching can also be done inadvertently if the unleaded fuel supply at a particular station or at a wholesale supplier becomes contaminated or deliberately switched with leaded gasoline. Although EPA estimates, however, that the nationwide contamination violation rate at retail gasoline stations is less than one percent. There are many possible reasons why people misfuel, but the primary reasons are thought to be price and the perception of enhanced performance, since leaded fuel is both cheaper and higher in octane rating than unleaded fuel.

EPA has been collecting data since 1978 on the occurrence of tampering and misfueling to assess the magnitude of the problem. Covert observation of vehicle owners at fueling stations and direct inspection of individual vehicles in roadside surveys have shown that nationally nearly one in five in-use vehicles have at least one emission control disablement and that a significant number of vehicle owners misfuel. These figures are alarming in light of the fact that it is a federal violation with large civil penalties for repair garages, dealerships or fleet operators to remove or disable emission control components and that many States have laws which make such disablements by individual vehicle owners illegal. Tampering and misfueling are, therefore, significant problems which current efforts have not adequately held in check.

Inspection and maintenance (I/M) programs are being instituted in some areas to assure a better state of repair for vehicles operated in large urban areas with air quality problems. The Clean Air Act Amendments of 1977 require I/M programs in urban areas which could not attain ozone or carbon monoxide air quality standards by 1982. Although these I/M programs will produce large reductions in HC and CO emissions, most programs do not explicitly require that all emission control components be in place and in good repair in order to pass the I/M inspection. The simple idle test which is used in most I/M programs is not designed to detect specific component disablements. Such I/M programs alone, therefore, will not completely solve that portion of the excess emissions problem due to tampering and misfueling. Additional emission reductions from reducing the occurrence of tampering and misfueling are possible in all areas in order to help meet or to maintain ambient air quality goals.

Tampering and misfueling, and thus the excess emissions caused by them, can be reduced in a variety of ways:

- In areas with I/M programs, an anti-tampering and anti-misfueling program could be added as part of the emissions program.
- In areas with an existing safety or other periodic inspection requirement, an anti-tampering and anti-misfueling program can be added to the inspection program. In areas without an existing inspection requirement, a new requirement can be implemented either on a periodic or change-of-ownership basis.

- Various field enforcement efforts can also be used in any area to deter tampering and misfueling.

Each of these three approaches is examined separately in Section 5.0, which discusses implementation issues as well as benefits.

In any approach, the potential benefits from anti-tampering and anti-misfueling programs will be affected by: 1) how much tampering and misfueling are occurring given existing efforts, if any, to control them; 2) the effectiveness of the program in reducing the observed rate of tampering and misfuelng; and 3) the effects of tampering and misfueling on the emissions from vehicles. There are two ways in which anti-tampering and anti-misfueling programs reduce excess emissions. First, a program will require repair and replacement of damaged or missing emission control components when they are discovered. Second, such a program will also result in deterrence of tampering and misfueling which would have occurred if the program had not been implemented. Any program's benefits will be some mix of these two elements although the design of the program may rely more on one than the other for program benefits.

This report does not cover specific methods of detection for disablements. The report briefly describes what each inspection would be like and covers general methods that can be used to detect disablements. A twenty-hour tampering detection training course is available from Colorado State University. This course provides hands-on experience in identifying the location and general functions of emission control devices. Colorado State University has also recently published a book titled "1968-1982 Automotive Emission Systems Application Guide". This book provides engine family specific information on what emission control components are original equipment on passenger vehicles and light-duty trucks. Also, in-the-field training can be provided by EPA inspectors to those jurisdictions interested in establishing tampering and/or fuel switching enforcement programs that are aimed at retail gasoline stations, fleet operations and repair facilities.

Section 2.0 will discuss the current knowledge about tampering and misfueling rates. Section 3.0 will examine the effects of misfueling and disablement of individual emission control components on vehicle emissions, discuss which vehicles are equipped with each emission component, and estimate the cost of repairs. Section 4.0 will discuss the calculation approach which was developed for this report to estimate the excess emissions caused by tampering and misfueling. Effectiveness will depend on the particular program approach and will, therefore, be discussed for individual approaches in Section 5.0. Section 6.0 explains how to use the MOBILE3 emission factor model to calculate program benefits.

This report analyzes four specific types of tampering--PCV, evaporative control system, air pump, and catalyst removal--plus misfueling. Catalyst removal and misfueling affect HC, CO, and NOx emissions; and the remaining forms of tampering affect only HC and CO. EGR tampering rates are also presented, but the emission increases due to EGR disablement and the potential benefits of an EGR tampering inspection will be the subject of a later report.

The potential benefits of a check for disabled closed-loop sensors have not been analyzed because of the uncertainty associated with identifying a tampering rate for these relatively new components. However, a gram per mile emission effect for disablement is listed. Tailpipe I/M tests can identify as much as 80% of the excess emissions associated with oxygen sensor tampering. Thus, in I/M areas an oxygen sensor check would have reduced benefits even if a significant tampering rate existed. Future tampering surveys will attempt to identify the existing closed-loop sensor tampering rate.

The most cost-effective portion of the emission reductions possible from a program to control tampering and misfueling is the portion that results from preventing new instances of tampering and misfueling, since no repair cost is incurred. Some jurisdictions may wish to inspect only cars sold after the program begins. For the convenience of such jurisdictions, benefits are shown in all tables for 1984 and later vehicles separately from those for older vehicles. One possible compromise between the larger benefits and costs of inspecting all model years and the reduced benefits of inspecting only newer vehicles is to inspect all 1980 and later model year vehicles. The tables have also separated the 1980 through 1983 model years for this purpose.

Because 1987 is the deadline for attainment of the ozone and carbon monoxide standards for areas which received extensions beyond the 1982 deadline, benefits are calculated for January 1, 1988.

2.0 TAMPERING AND MISFUELING RATES

2.1 Current Rates

Since 1978, EPA has conducted surveys of in-use vehicles, both passenger cars and trucks, in seventeen states and collected data regarding emission component disablements and misfueling from over 8,000 vehicles. The latest of these surveys completed in 1982 [1]*, collected data from nearly 3,000 cars in ten states. All of the surveys were conducted either at a roadside check in conjunction with a random police roadside pullover or as a special, temporary addition to a safety or I/M inspection at state-run or private inspection stations. Although the inspections were voluntary, efforts were made to assure as complete participation as possible. Once a city and specific site in the city were chosen, vehicles were chosen completely at random, although the surveys since 1980 inspected only 1975 and later model year vehicles. Table 1 presents a summary of the sample sizes collected in the various states in the 1982 tampering survey. Notation has been added to indicate I/M areas with the program start date and the type of vehicle recruitment used in the survey at that site.

The 1982 survey was chosen as the definitive data base with which to calculate current and future tampering rates. Comparing the 1982 survey with the previous survey shows that tampering and misfueling behavior has changed with time, and therefore the latest survey will more clearly match future tampering and misfueling behavior. Also, the 1982 survey was more successful than previous surveys in obtaining an essentially non-voluntary and therefore unbiased sample.

Table 2 shows the tampering rates observed for the 1975 and later vehicles in the 1982 survey. Table 2 indicates that with the exception of EGR, PCV and evaporative canister tampering, tampering rates are on average lower in cities with I/M programs. Later in this chapter an analysis will be made which more exactly identifies the impact of I/M programs on tampering and misfueling rates.

Not all instances in which there was evidence of tampering or misfueling are reflected in Table 2. For example, tampering with air cleaner housings is not shown, nor is tampering with crankcase fresh air hoses. Only those cases in which the tampering was judged to be easily identifiable and to be sufficient to cause substantial quantifiable increases in emissions are included in Table 2. Consequently, Table 2 may differ from other published summaries of the 1982 survey.

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*Numbers in brackets refer to references at the end of the report.

Table 1

EPA 1982 Tampering
Survey Sample Sizes

State	Date I/M Program Started	Sample Size	Date of Tampering Survey	Type of Recruitment
FL	n.a.	307	4/82	a
LA	n.a.	183	4/82	b
MN	n.a.	307	8/82	a
NV*	7/81*	275	9/82	d
NJ	2/74	290	7/82	a
OK	n.a.	282	5/82	b
OR	7/75	310	9/82	c
RI	1/79	324	7/82	a
TX	n.a.	293	4/82	b
WA	1/82	312	9/82	c
Total		2883		

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*Prior to 10/83, Nevada's I/M program required inspection only on change of ownership.

a: Random roadside pullover.

b: As part of a centralized or decentralized safety inspection.

c: As part of a centralized or decentralized I/M inspection.

d: Vehicles were recruited at a parking lot.

Table 2

Current Tampering and Misfueling Rates* From 1982 Tampering Survey

Emission Control System	I/M Sites		Non-I/M Sites	
	LDV	LDT	LDV	LDT
PCV	1.1%	3.4%	1.0%	4.4%
Evaporative	1.4%	3.4%	0.4%	6.1%
Air Pump	3.1%	2.9%	6.1%	13.8%
Catalyst	1.7%	5.0%	4.5%	19.5%
EGR	9.9%	10.8%	8.2%	15.2%
Habitual Misfueling**	5.3%	12.4%	9.4%	25.0%
Filler Inlet Restrictor	3.2%	8.3%	6.6%	18.5%
For Comparison Only:				
All Misfueling***	6.5%	12.4%	11.6%	31.0%
(Number of Vehicles)	(1055)	(146)	(1143)	(229)

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*Grossly tampered cars only. See text.

**Defined as an enlarged fuel inlet restrictor or leaded fuel (lead content greater than 0.05 gm/gal) in tank. Catalyst vehicles only. See text in Section 2.1 for discussion.

***Defined as an enlarged fuel inlet restrictor, leaded fuel (lead content greater than 0.05 gm/gal) in tank, or lead compounds detected in the tailpipe. Catalyst vehicles only. The detection of lead deposits alone is not used as an indication of habitual misfueling in this report for reasons given in the text. A positive result on the test for lead deposits is believed to be an accurate indication that at least some leaded fuel has been used, however. The rates for "all" misfueling shown in this table are for comparison only.

The interpretation of the 1982 survey data to determine which instances of tampering were sufficient to cause substantial quantifiable increases in emissions was straightforward except for misfueling. The survey examined three vehicle parameters relative to misfueling: (1) whether the lead content of the fuel in the tank was over the legal limit of 0.05 gram/gallon; (2) whether the fuel inlet restrictor had been enlarged enough to allow a leaded fuel nozzle to be used; and (3) whether lead sensitive "Plumbtesmo" test paper[2] detected lead deposits in the tailpipe. To result in deactivation of the catalyst and substantial long term emission increases, it is believed misfueling must be either repeated at least three or four times in succession, or, if not done consecutively, must occur with a fairly high frequency over a long period of time. Such consecutive or frequent misfueling is called habitual. As discussed below, no combination of the parameters examined in the 1982 survey are definitive indicators of this.

Each of the three misfueling parameters examined in the survey has shortcomings in that habitually misfueled cars may escape detection. Checking the inlet restrictor does not detect: (1) vehicles whose owners have misfueled using funnels or illegally small nozzles; (2) vehicles which are victims of fuel mislabeling by gas stations or distributors; or (3) vehicles which have otherwise used contaminated gasoline. Fuel samples drawn on a one-time basis cannot detect vehicles which were misfueled regularly in the past, but for some reason, e.g., change of owners, have not been misfueled recently. Available information does not rule out the possibility that the lead sensitive Plumbtesmo test paper may detect vehicles which have only been misfueled a couple of times at wide intervals and have catalysts which are still active. The test paper can also fail to detect vehicles which have had tailpipe replacements since the last misfueling episode.

The inlet restrictor check can be assumed to have few false positives, since an owner is extremely unlikely to have tampered with the restrictor for no reason. Past or current habitual misfueling is therefore assumed whenever a tampered inlet is found.

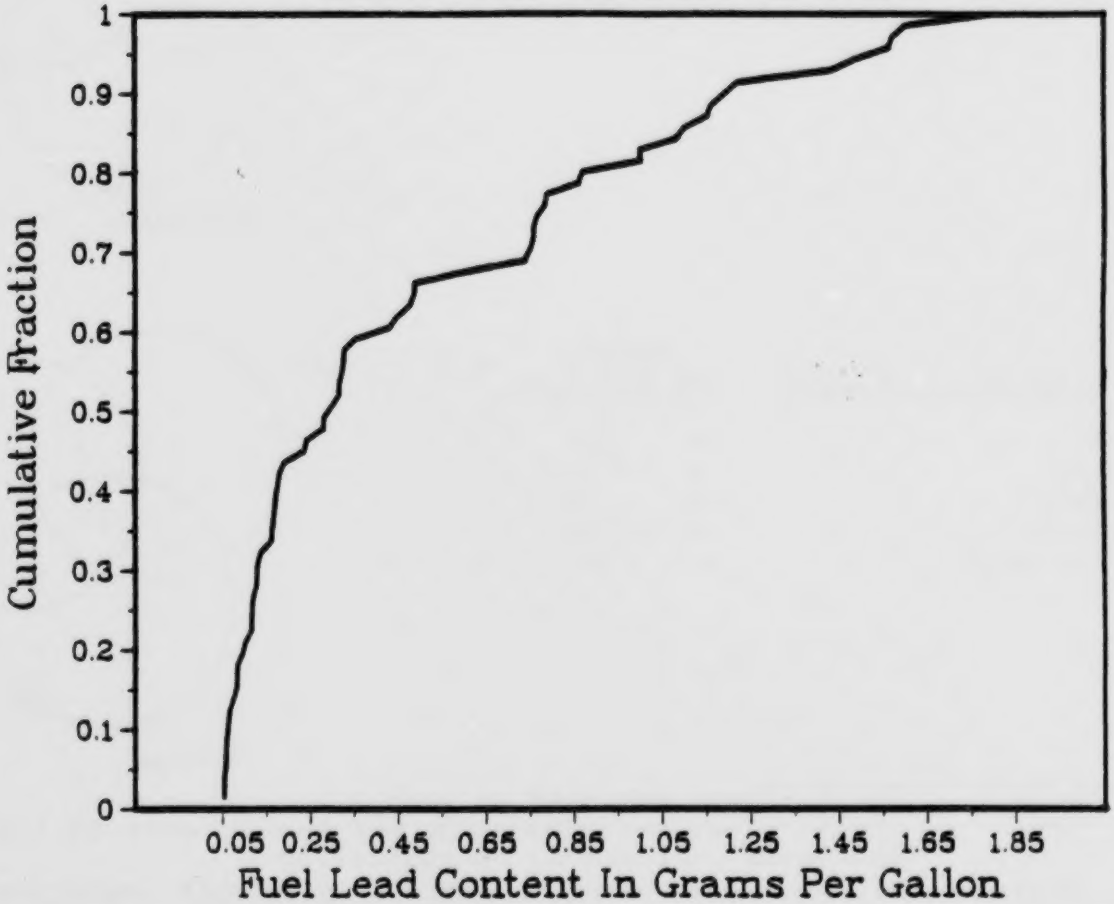
The check on fuel lead content is a definite identifier of those cases where leaded fuel has been used recently. Information on the observed lead concentrations of vehicles over the legal limit but with intact inlet restrictors is presented in Figure 1. Most of the vehicles with fuel over the legal lead limit were well over it, so low level contamination of unleaded fuel cannot possibly be the cause in these cases. Many of the cars clearly had filled with leaded fuel at the last fillup. Based on EPA fuel inspections and other fuel surveys, it is far more likely that leaded fuel was purchased knowingly than that the gasoline retailer had sold leaded fuel from a pump labeled unleaded. Given that the owner knowingly bought leaded fuel recently, it is likely that the vehicle has been habitually misfueled. Evidence that owners who use leaded fuel once tend to do so regularly is discussed in the last paragraph of this section.

The only remaining issue, then, is whether a vehicle which has a Plumbtesmo test paper result indicating misfueling, but which does not have other indications of misfueling, has actually been misfueled enough to deactivate the catalyst. Since the fuel in the tank is below the legal lead limit, it is certain that unleaded fuel has been used for at least the last two or three fillups. The most plausible scenario for earlier habitual misfueling would be that a previous owner had misfueled extensively using a funnel or illegally small nozzle but that the present owner does not. This is clearly a possibility, particularly for older cars, but is tempered by the low rate of owner turnover. It is also possible that a family car was or is misfueled habitually by one member of the family but not by the member who filled the tank the last few times. A single vehicle operator may also have habitually misfueled only during the last gasoline crisis, in 1979, when unleaded fuel may have been difficult to obtain. Otherwise there is little reason to believe that the same owner would stop habitual misfueling once he or she started. The other possibility, as mentioned, is that leaded fuel has been used only a couple of times, for whatever reason and perhaps unknowingly.

Because of the uncertainty as to how to handle the vehicles which failed only the test paper results, EPA has chosen for this report to include only the fuel lead content and inlet restrictor as evidence for calculating habitual misfueling rates. As can be seen in Figure 2, this decision reduces the number of vehicles with any indication of misfueling that are considered habitually misfueled by about 18% for the passenger cars and 15% for the light-duty trucks. For the reader's information, Table 2 shows the misfueling rate based on these two indicators alone and on all three indicators. EPA will be considering ways to reduce the uncertainty in this area and may provide further information later.

An analysis of fueling habits was recently performed by a Department of Energy contractor using data from detailed diaries kept by families on their gasoline purchases[3]. (Data used for the fuel diary analysis is voluntary and therefore may misrepresent the true incidence and patterns of misfueling.) The DOE analysis showed that among the families keeping diaries, more than 85% of the leaded fuel purchased was purchased by vehicle owners who misfuel more than 50% of the time. This suggests that a given owner rarely stops his or her habitual misfueling once started, but says nothing about previous owners. This analysis supports the assumption used in this report that evidence of deliberate misfueling, such as a tampered filler inlet, usually indicates habitual misfueling. The diaries have not yet been analyzed to determine exactly how many vehicles were affected by serious misfueling during the diary period.

Figure 1

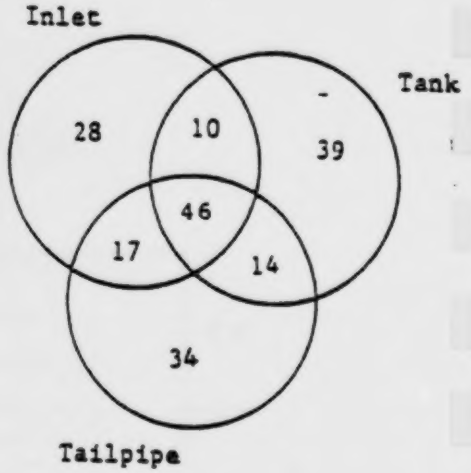


Distribution of Lead Content for Those Passenger Cars in the 1982 Tampering Survey Which Had Fuel Lead Content Greater Than 0.05 Grams Per Gallon

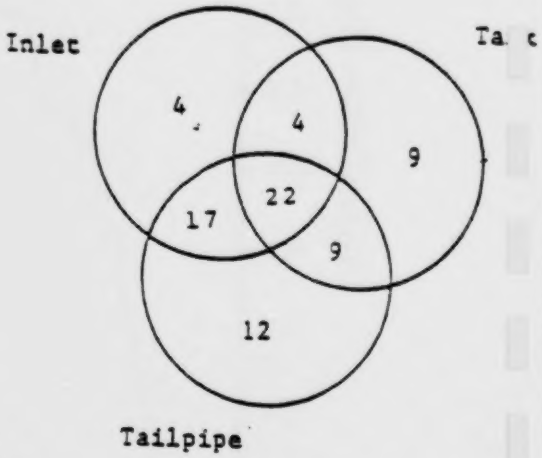
Figure 2

Overlap Among Indicators of Misfueling in the 1982 EPA Tampering Survey*

Passenger Cars:		Number of Vehicles
All	=	2207
Any	=	188
Tank	=	109
Inlet	=	101
Tailpipe	=	111



Light-Duty Trucks:		Number of Vehicles
All	=	351
Any	=	77
Tank	=	44
Inlet	=	47
Tailpipe	=	60



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*All:	All catalyst vehicles in sample.
Any:	All catalyst vehicles with any one or more of the following indications of misfueling
Tank:	All catalyst vehicles whose fuel sample indicates a fuel lead content greater than 0.05 grams per gallon.
Inlet:	All catalyst vehicles whose fuel inlet restrictor allows entry of a leaded fuel nozzle.
Tailpipe:	All catalyst vehicles whose tailpipe lead deposits indicate past use of leaded fuel.

2.2 Future Rates

In order to estimate the excess emissions caused by tampering and misfueling on a future date, January 1, 1988, for example, it is necessary to predict the tampering and misfueling rates when the average age of the vehicles will be older than observed in the 1982 survey. Examination of the data from the 1982 survey shows a marked increase in the tampering rates of some components, including catalysts, and in misfueling rates as the average mileage of the sample increases. This increase is illustrated in Figures 3 through 9. Consequently, the dependence of tampering rates on mileage must be accounted for.

To examine this issue, a linear regression equation on mileage was fit to data from the 1982 EPA survey and appears to reasonably explain the tampering and misfueling rates observed in the surveys. Some of the regression lines are also shown in Figures 3 through 9. Each linear equation is defined by a zero mile rate and an increase in the rate for every 10,000 miles of fleet average mileage. Other non-linear equations did not seem to better explain the increase. It was decided, therefore, to use the linear equation to estimate the tampering and misfueling rates on January 1, 1988, using standard EPA predictions of the average age in miles of each model year on that date.

Least squares regression was used to estimate a line of the form Y = bX+a, where Y is the proportion of tampered vehicles at mileage X. The data used to generate estimates of the regression coefficients, a and b, were the mileage and whether the vehicle was tampered (Y=1) or not (Y=0) for each vehicle in the 1982 tampering survey.

Least squares regression, as used in our case, requires several assumptions concerning the distribution of Y for fixed X in order to estimate the error variance of a and b. Ordinarily, the Y values are assumed to be normally distributed for each value of X. Further, it is assumed that the variances for these Y distributions are equal at all points along the line. Since the Y values in our data are either zero or one, neither of these assumptions are met. However, an investigation of the properties of the least squares estimators has shown that they remain unbiased even in the presence of a binary dependent variable. Since it is unnecessary to obtain error estimates for the regression coefficients for this application, it was determined that the simple least squares regression approach is sufficient for this application.

In calculating equations to predict tampering and misfueling rates, several factors have been considered. The rate of tampering and misfueling among passenger cars and among trucks is significantly different. Therefore, each of these vehicle types were treated separately. Also I/M areas tend to have lower tampering and misfueling rates than areas without I/M programs. Each of these two classifications is, therefore, also treated separately. All vehicles surveyed in Portland were eliminated since Portland conducts a tampering inspection in conjunction with its I/M emissions test.

Although local tampering and misfueling rates can vary greatly, only one set of tampering rate equations is used in this report. If a particular area has reason to believe, or has data from the 1982 or 1983 tampering survey which show that tampering or misfueling rates are higher in its area than in the nation as a whole, EPA is willing to evaluate the evidence and estimate benefits specific to that area. In fact, EPA will require the use of valid local survey data where it is available.

In order for a local survey to be considered valid, the established EPA survey procedures must be followed. Therefore, areas that are interested in using local survey data should contact the Field Operations and Support Division before conducting the survey to be sure that the results will be acceptable. Also, in order to use local light-duty truck tampering rates a sufficient sample of trucks will be required.

If a state or local jurisdiction wishes to use a known or estimated local VMT fraction for light-duty trucks that is more than 25% higher than the national average VMT fraction, EPA will assign a default tampering rate which will be calculated from that subset of survey sites which have higher than normal LDT populations. Alternatively, an EPA approved local survey may be used to determine a local specific rate. EPA tampering surveys have shown that light-duty truck tampering rates are much higher for some components on a national basis than those for light-duty vehicles. EPA is unwilling to assume however, that areas with high light-duty truck VMT have proportionally more serious truck tamperers. Consequently, local data on tampering rates for light-duty trucks will be required, unless the jurisdiction is willing to use the default rate discussed above or assumes a national average VMT fraction.

Since there are no data in the 1982 survey from model years before 1975, and since these vehicles should have little effect on the overall benefits in 1987, it has been assumed that tampering rates for pre-1975 cars are the same as for 1975 and later passenger cars at equal mileages. It is also assumed that the tampering and misfueling behavior of 1981 and later model year passenger car owners will not be significantly different in future years than the behavior of pre-1981 passenger car owners, for those components treated in this report. Both of these assumptions are unproven, but the data available are not adequate to treat these groups separately. The assumption for 1981 and later vehicles may not be necessary in future versions of this document, since more data on 1981 and later vehicles at higher mileages will be available then.

In addition, truck sample sizes are inadequate to estimate the rate of increase of tampering and misfueling for trucks, therefore, the rate of increase in tampering and misfueling for passenger cars has been assumed for trucks also, although the zero mile rates have been adjusted to reflect the observed differences in the average tampering and misfueling rates between trucks and passenger cars.

Table 3 presents the linear regression equation coefficients calculated from the tampering survey data. The equations describe the relationship of tampering and misfueling rates to vehicle mileage in the non-I/M areas. The light-duty truck zero mile rate values were calculated using the overall truck tampering and misfueling rates and average mileage and projecting backwards to zero miles assuming the same increase in rate as for passenger cars.

Table 4 presents the same information but for the I/M sample, assuming no formal tampering check. Differences in the design and history of the I/M programs had to be overlooked in the interest of retaining a meaningful sample size.

Logically, an ordinary I/M program should have little affect on EGR, PCV and evaporative canister tampering, since they have little or no affect on idle HC and CO exhaust emissions measured in I/M programs. Consequently, the tampering rates for these components have been calculated using both I/M and non-I/M areas combined.

In both Table 3 and Table 4, some linear equations contain negative zero mile rates. Since these negative levels are small, no effort has been made to force the equation through zero. If, however, a tampering or misfueling rate for a particular model year is calculated to be less than zero in the evaluation year, that rate for that model year is set to zero.

In both Table 3 and Table 4, overlap among tampering types is ignored, so one car can contribute to several of the regression equations. The overall tampering rate at a given mileage is, therefore, less than the sum of these equations. In estimating excess emissions due to tampering and the benefits of controlling tampering, it is necessary to explicitly account for vehicles with more than one form of tampering, since tampering effects are not always additive. Following sections will describe how this was done for each case.

It is unlikely that a local tampering survey would inspect enough vehicles to allow a reliable estimate to be made of the dependence of tampering on vehicle mileage. Instead, the outcome of a local survey is likely to be only the knowledge that the tampering rate for a given component was a certain value for a group of vehicles of a certain average mileage. However, to estimate benefits, predictive equations that include mileage effects are needed. EPA will address this need as follows. If the local tampering rate for a vehicle type (car or truck) is higher than the corresponding national rate, the national equation will be adjusted by increasing the zero-mile constant but the mileage coefficient will be unchanged, as done above for light-duty trucks in the national case. If the local rate is lower than the corresponding national rate, both the zero-mile constant and mileage coefficient will be reduced proportionally to the rates of the local and national tampering rates at equal mileages. Using an equal slope for rates lower than the national averages would result in potentially unreasonable mileage intervals before tampering begins. Using a proportional adjustment for rates higher than the national averages would create potentially unreasonable slopes for tampering rates. The approach used moderates the potential problems by using a different method for each case.

Table 3

National Average Tampering Rate Prediction Equations for Non-I/M Areas

Tampering Rate = (zero if mileage is less than M_o)
(A + B x (mileage) otherwise)

Emission Control Component	"M_o" (miles)		"A" (%)		"B" (%/10K)	Rate at 50,000 Miles (%)	
	LDV	LDT	LDV	LDT	Both	LDV	LDT
Air Pump	10,219	0	-2.71	4.89	2.652	10.55	18.15
Catalyst	12,104	0	-1.95	13.53	1.611	6.11	21.59
PCV System*	0	0	0.02	3.08	0.248	1.26	4.32
Evaporative* Canister	14,328	0	-0.48	3.77	0.335	1.20	5.45
Filler Inlet	7,072	0	-1.43	11.01	2.022	8.68	21.12
Other Misfueling**	0	0	1.65	6.96	0.559	4.45	9.76
EGR System	273	0	-0.06	5.02	2.199	10.94	16.12

---

*EGR, PCV and evaporative canister tampering rates are assumed to be the same in I/M and non-I/M areas.

**Defined as leaded fuel (lead content greater than 0.05 gm/gal) in tank. Catalyst vehicles only. See text in Section 2.1 for discussion.

Table 4

National Average Tampering Rate Prediction Equations for I/M Areas

Tampering Rate = (zero if mileage is less than M_o)
(A + B x (mileage) otherwise)

Emission Control Component	"M_o" (miles)		"A" (%)		"B" (%/10K)	Rate at 50,000 Miles (%)	
	LDV	LDT	LDV	LDT	Both	LDV	LDT
Air Pump	9,091	9,001	-1.01	-1.00	1.111	4.55	4.56
Catalyst**	2,397	0	-0.11	3.32	0.459	2.19	5.62
PCV*	0	0	0.02	3.08	0.248	1.26	4.32
Evaporative* Canister	14,328	0	-0.48	3.77	0.335	1.20	5.45
Filler Inlet		0	-0.77	4.70	1.000	4.23	9.70
Other Misfueling**	12,987	0	3.82	6.99	-0.211	2.77	5.94
EGR System	273	0	-0.06	5.02	2.199	10.94	16.12

---

*EGR, PCV and evaporative canister tampering rates are assumed to be the same in I/M and non-I/M areas.

**Defined as leaded fuel (lead content greater than 0.05 gm/gal) in tank. Catalyst vehicles only. See text in Section 2.1 for discussion.

Figure 3

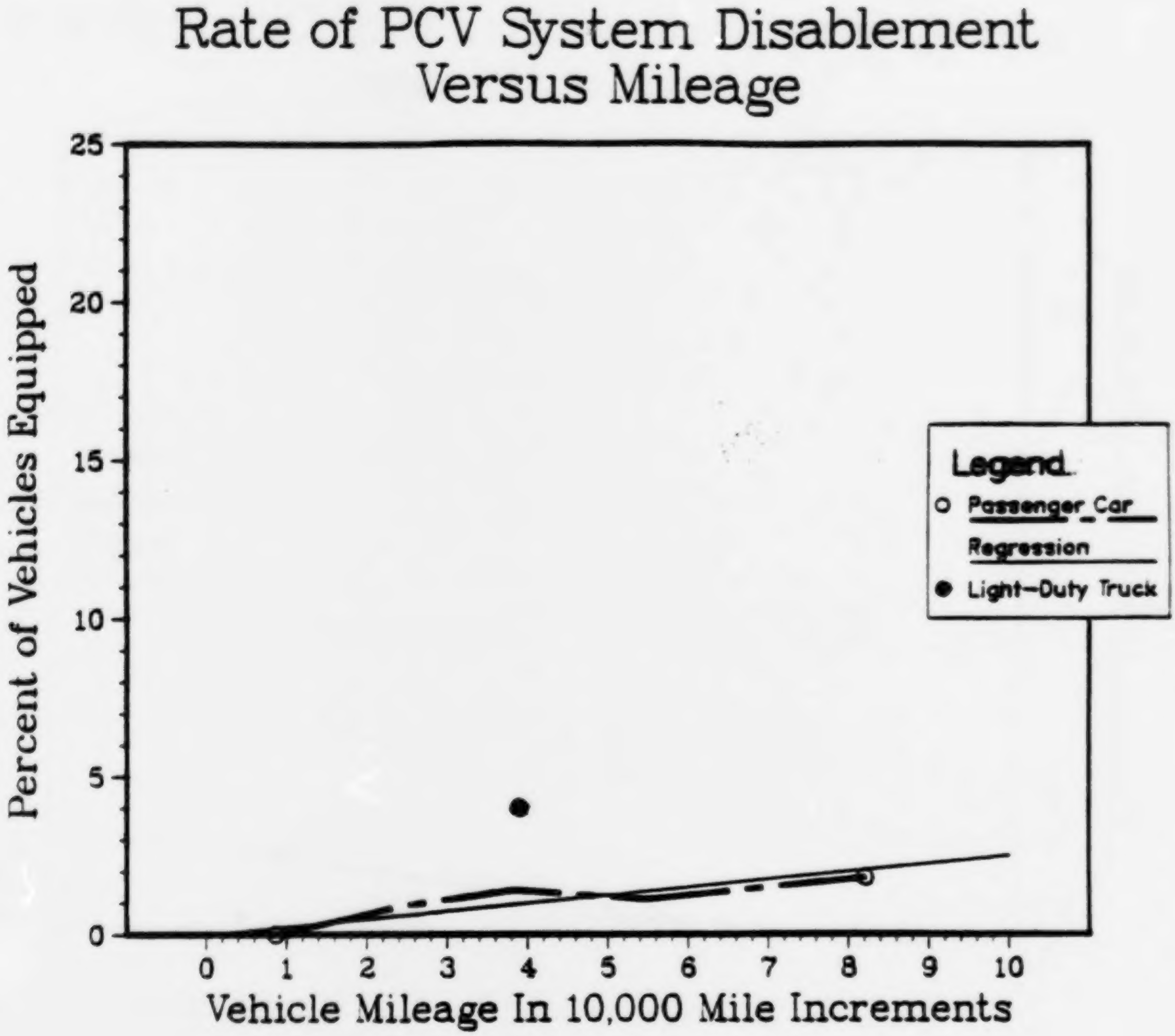

Rate of PCV System Disablement
Versus Mileage
Percent of Vehicles Equipped
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Vehicle Mileage In 10,000 Mile Increments
Legend
○ Passenger Car
Regression
● Light-Duty Truck

Figure 4

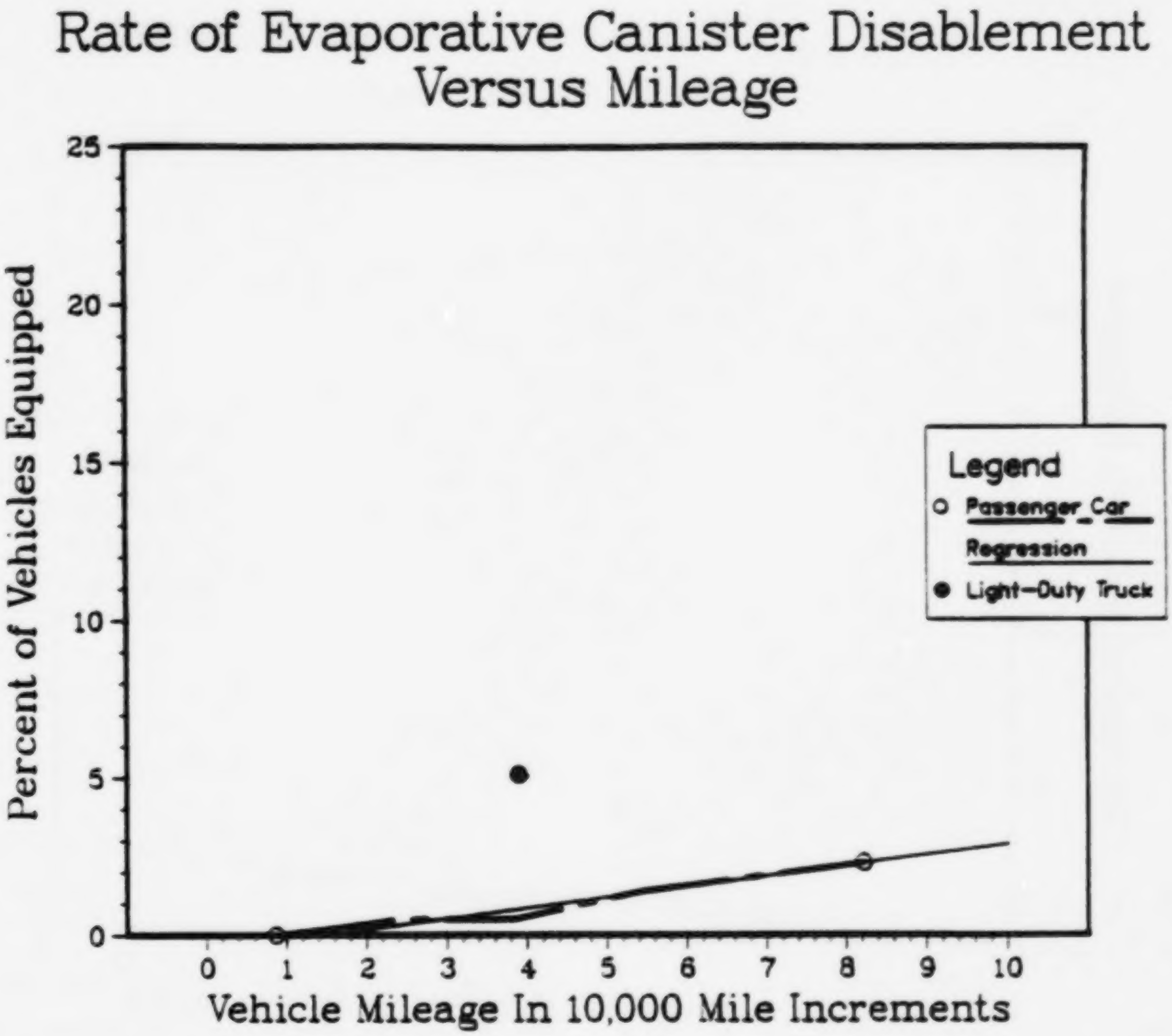

Rate of Evaporative Canister Disablement Versus Mileage
Percent of Vehicles Equipped
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Vehicle Mileage In 10,000 Mile Increments
Legend
○ Passenger Car
Regression
● Light-Duty Truck

Figure 5

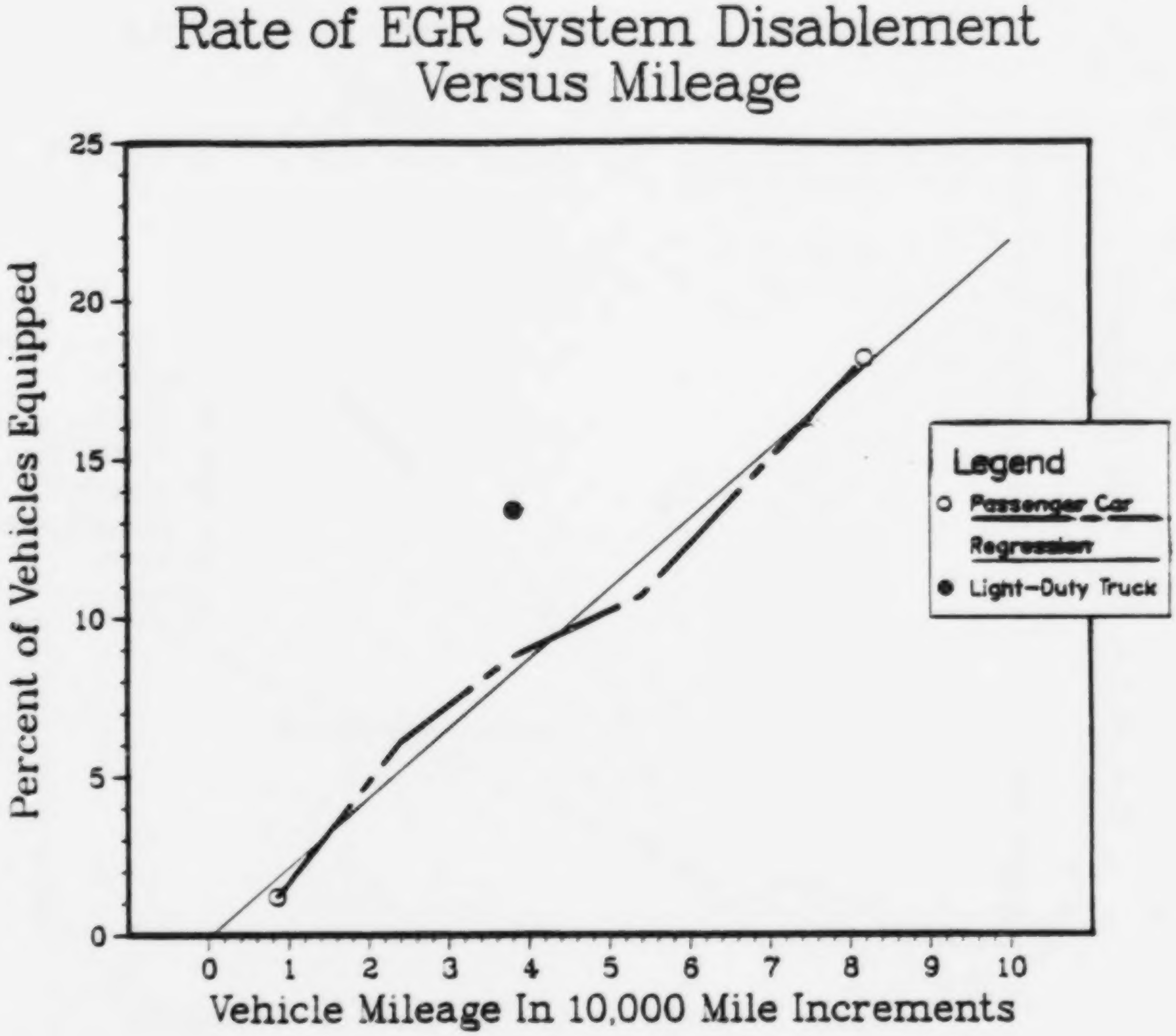

Rate of EGR System Disablement Versus Mileage
Percent of Vehicles Equipped
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Vehicle Mileage In 10,000 Mile Increments
Legend
Passenger Car
Regression
Light-Duty Truck

Figure 6

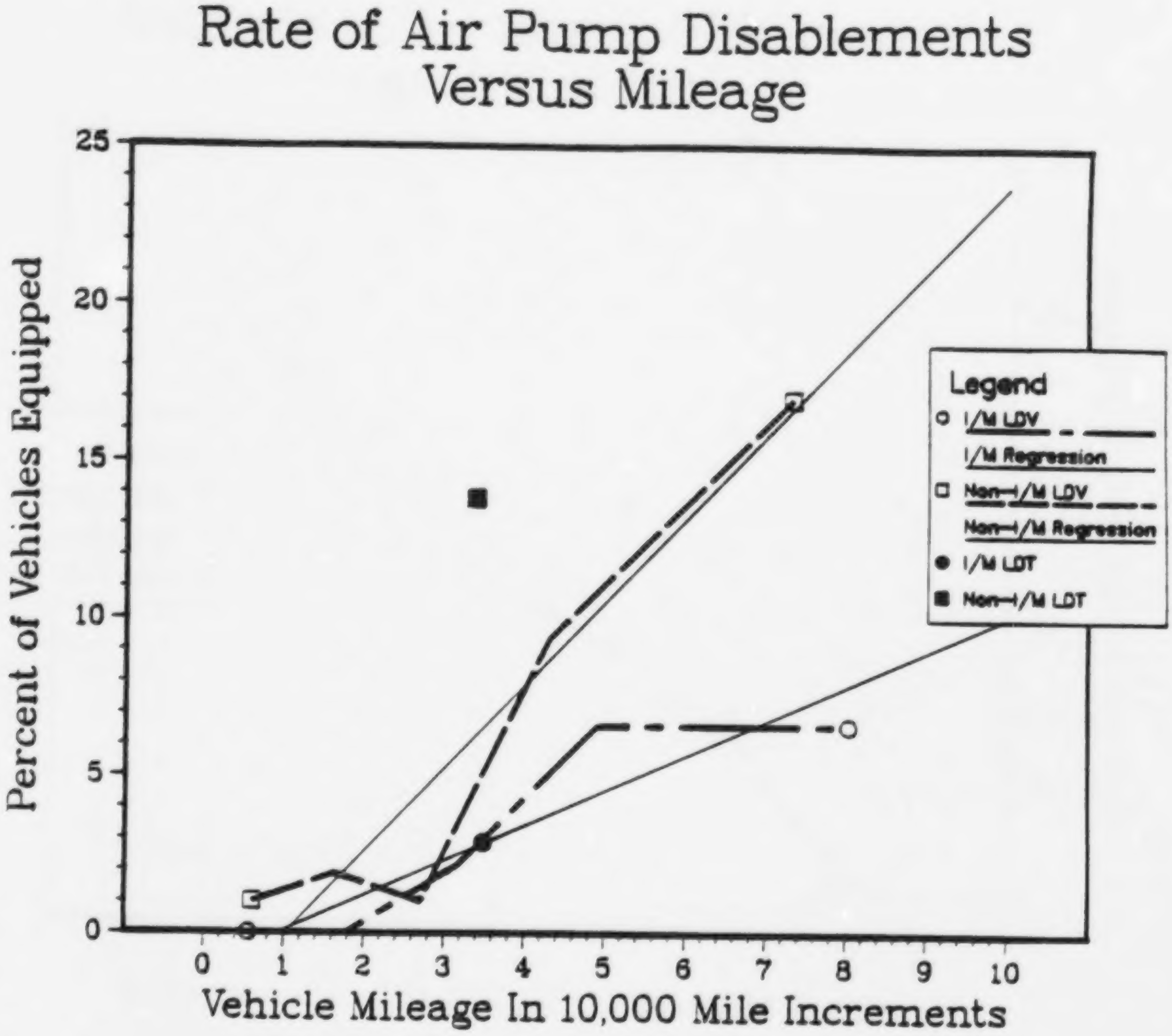

Rate of Air Pump Disablements
Versus Mileage
Percent of Vehicles Equipped
25
20
15
10
5
0
Vehicle Mileage In 10,000 Mile Increments
0
1
2
3
4
5
6
7
8
9
10
Legend
○ I/M LDV
I/M Regression
□ Non-I/M LDV
Non-I/M Regression
● I/M LDT
■ Non-I/M LDT

Figure 7

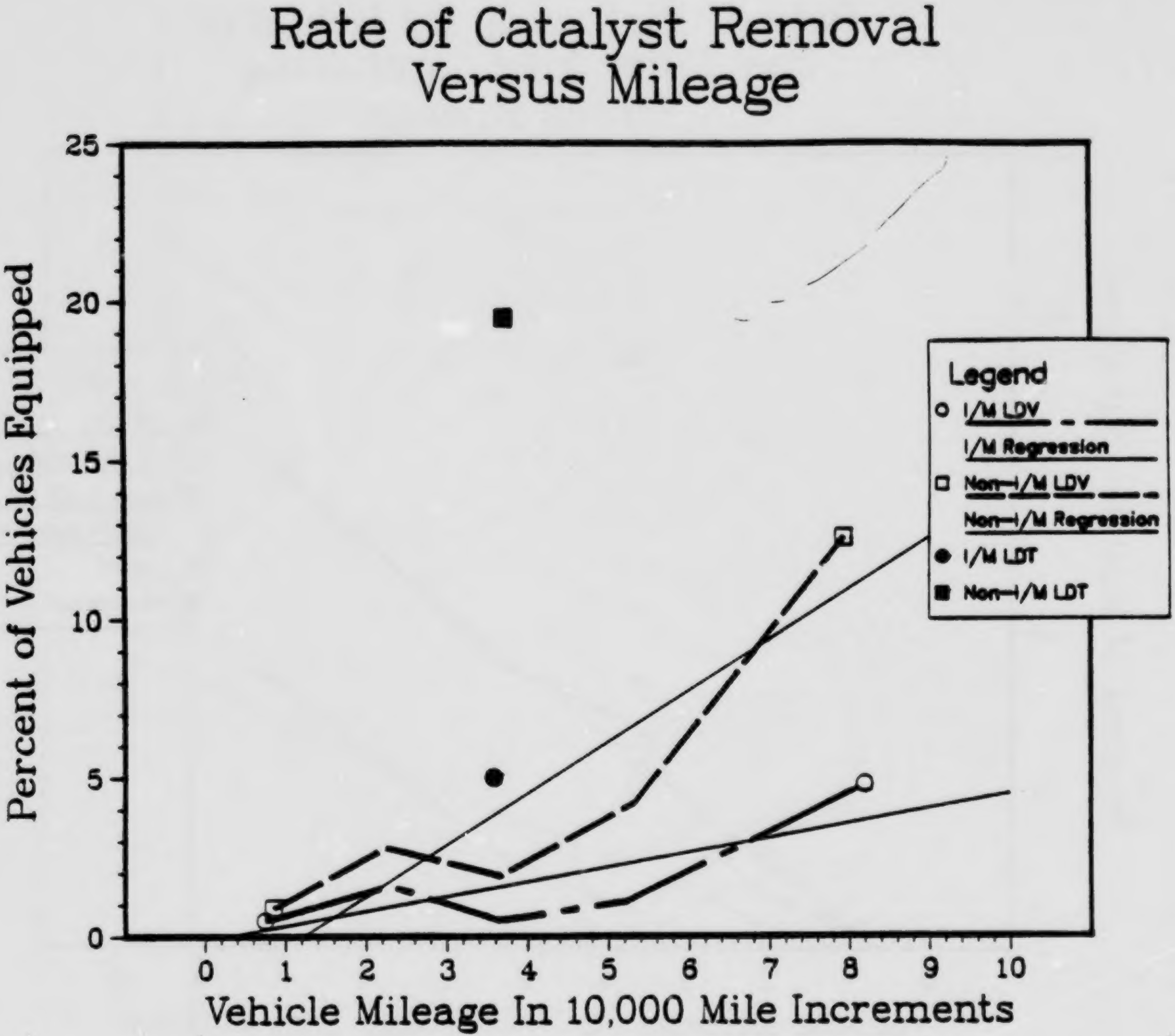

Rate of Catalyst Removal
Versus Mileage
Percent of Vehicles Equipped
0
5
10
15
20
25
Vehicle Mileage In 10,000 Mile Increments
0
1
2
3
4
5
6
7
8
9
10
Legend
○ I/M LDV
I/M Regression
□ Non-I/M LDV
Non-I/M Regression
● I/M LDT
■ Non-I/M LDT

Figure 8

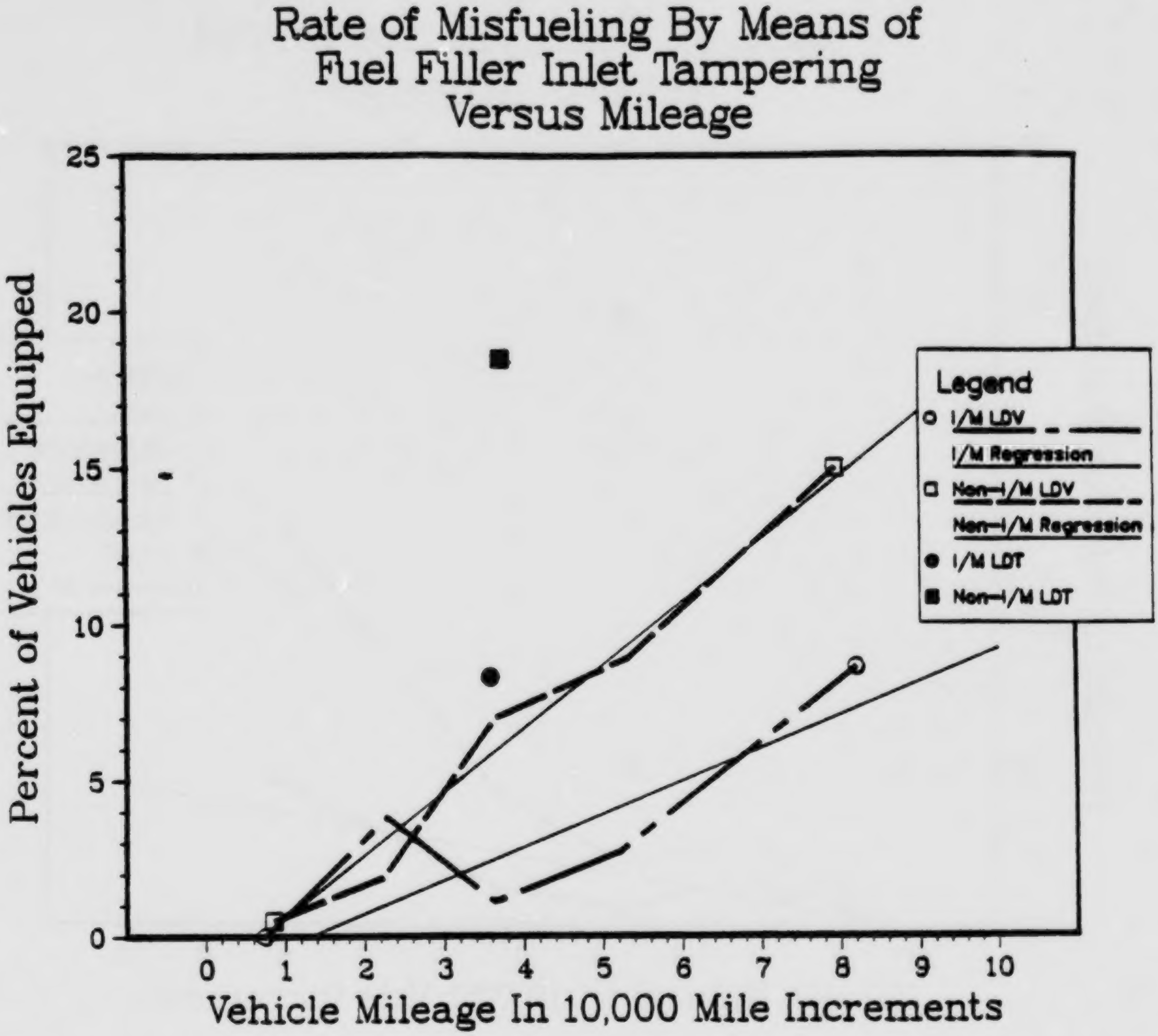
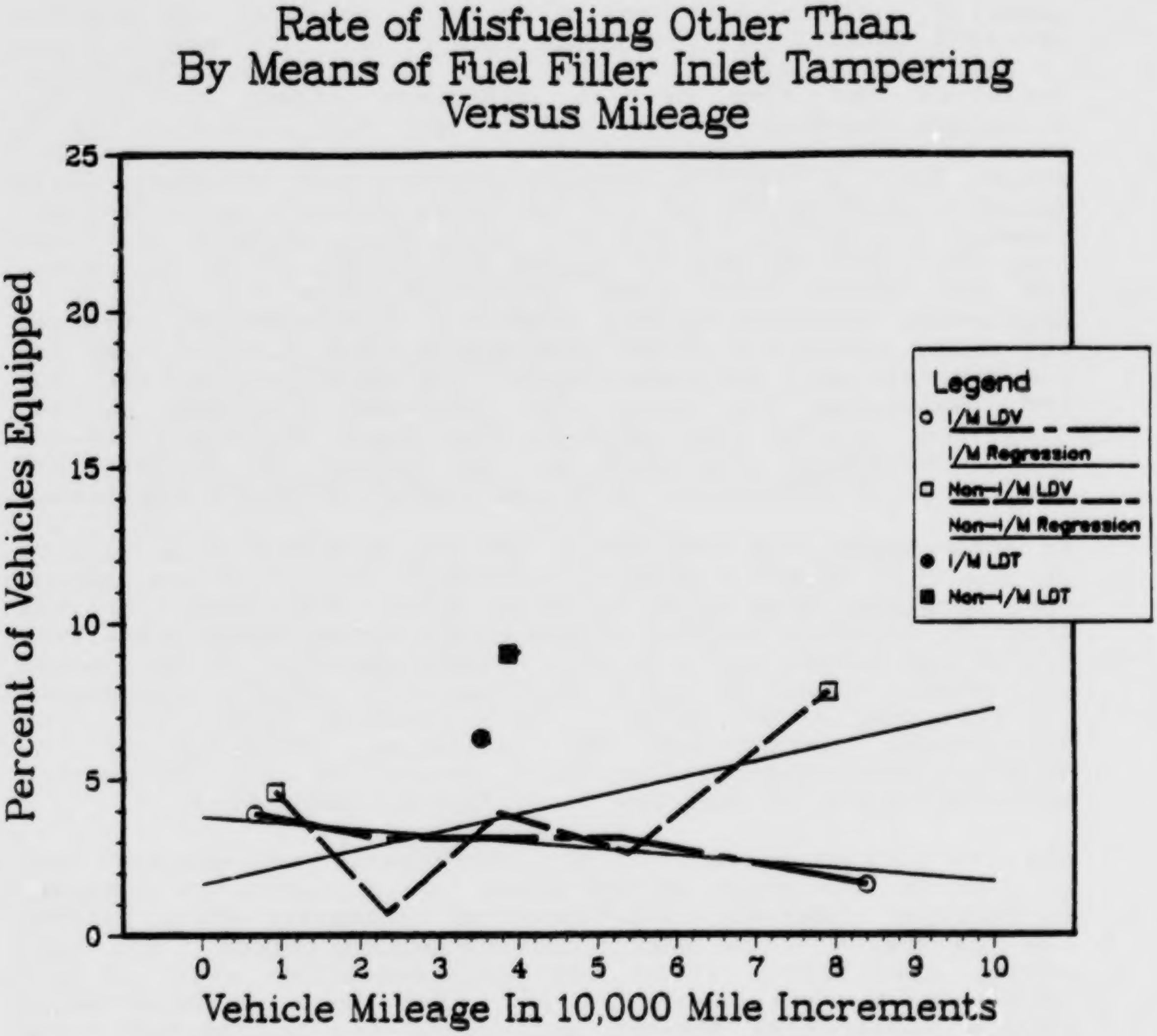

Rate of Misfueling By Means of
Fuel Filler Inlet Tampering
Versus Mileage
Percent of Vehicles Equipped
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Vehicle Mileage In 10,000 Mile Increments
Legend
○ I/M LDV
I/M Regression
□ Non-I/M LDV
Non-I/M Regression
● I/M LDT
■ Non-I/M LDT

Figure 9


Rate of Misfueling Other Than
By Means of Fuel Filler Inlet Tampering
Versus Mileage
Percent of Vehicles Equipped
0
5
10
15
20
25
Vehicle Mileage In 10,000 Mile Increments
0
1
2
3
4
5
6
7
8
9
10
Legend
I/M LDV
I/M Regression
Non-I/M LDV
Non-I/M Regression
I/M LDT
Non-I/M LDT

3.0 EFFECTS OF TAMPERING AND MISFUELING AND COSTS OF REPAIRS

The effect of a particular disablement of a specific emission control component on vehicle emissions is not easy to quantify. There are many different varieties of similar emission control devices which can differ from manufacturer to manufacturer and from model year to model year. Different varieties can also have a different effect on vehicle emissions depending on the engine type and overall state of tune as well as the condition of other emission control components. A testing program which would evaluate every possible combination of all of these factors would require immense resources. There has been some testing performed over the years by EPA to assess the impact of disablements. FTP and other tests were performed with and without a particular emission control component disconnected. Usually all other emission control components were in operation and the vehicles were in proper tune. The emission increases due to disablement may vary for vehicles in less perfect condition, however EPA believes that these tests provide the best information available on the impact of in-the-field tampering and misfueling on an individual vehicle's emissions.

In this report the individual vehicle benefits from repairs of specific emission control component tampering are taken, when possible, from these types of data. When practical, the existing data are further divided into appropriate model year technology groups to take into account changes in the design and effectiveness of particular emission control components in different model years. When adequate test data from disablement testing are not available, estimates of the benefits were made based on known controlled and uncontrolled emission levels of vehicles of different model years.

The few jurisdictions with NOx attainment problems may want to consider including an EGR check in an inspection program. In fact, an under-the-hood tampering inspection which ignores the EGR system - the most common tampering target - may lack public credibility after its implementation even if NOx reductions are not needed locally, since public understanding of the differences between pollutants may be limited. NOx emission reductions from anti-tampering and anti-misfueling programs will be addressed at a later date.

3.1 Air Pump

The purpose of the air pump is to supply air to the engine's exhaust in order to promote the oxidation of HC and CO to harmless by-products. The air pump performs this function on both catalyst and non-catalyst vehicles. The air pump is driven by means of a belt which transmits power from the crankshaft as it rotates. This method of powering the air pump is the same as that used to run the alternator and air conditioner compressor. The air pump can, therefore, be found near or on the same plane as the alternator or air conditioning compressor. Its plumbing distinguishes it. Some vehicles are equipped with pulse-air systems which also supply supplemental air to the exhaust stream but without a belt driven pump. Disablement of these systems is less frequent than for air pump systems and identification of disabled pulse air systems is not always as easily accomplished; therefore, this section will deal solely with disabled air pump systems.

The percentage of vehicles equipped with air pumps varies by model year. An analysis of the occurrence of air pump systems on passenger vehicles in the EPA Emission Factor data base was used to establish estimates of the percentage of vehicles in each model year group prior to 1984 equipped with air pump systems. The percentage for 1984 and later vehicles was projected. The resulting estimates are shown in Table 12 through 14 at the end of this section.

There are three ways the air pump is normally disabled. First, the belt which drives the pump can be removed. Second, the entire unit -- pump, belt, flexible hoses, steel piping, and even mounting brackets -- can be removed. Third, the output hose from the air pump can be disconnected and/or the air routing valve can be damaged. This last disablement results in the air pump spinning freely and no air being supplied to the exhaust. For purposes of this report, it is assumed that all three of these forms of disablement can be readily identified by trained inspectors.

The repairs necessary for these various forms of disablement are self-evident. In most cases, repair can be accomplished by simply installing a new belt or reconnecting a hose. An average repair cost of $20 has been assumed for this analysis. This estimate takes into account the few cases in which an expensive repair or reinstallation of an air pump is expected to be required.

The HC and CO emission increases which accompany air pump disablement for oxidation catalyst vehicles were quantified by examining data from 13 vehicles (1975-1976 model years) tested with and without their air pumps operational. All of these vehicles came from the 300-car Restorative Maintenance program. The vehicles are listed with their before and after emission levels in the Appendix. The results are summarized in Table 5. (One source of uncertainty in the analysis has to do with the fact that the vehicles used to determine the emission effects of air pump disablement were all in tuned-up condition. The emission increases due to air pump disablement for vehicles in less perfect condition may vary.)

Table 5

Increase in HC and CO Emissions Due to Air Pump Disablement

Technology	Increase in HC Emissions (gm/mi)	Increase in CO Emissions (gm/mi)
Oxidation Catalyst	1.37	30.61
3-way Catalyst	0.51	16.29

For three-way catalyst vehicles, the effects of air pump disablement were quantified by examining the results of EPA laboratory programs which took three vehicles representative of three-way catalyst technology and tested them with and without their air pumps operational. In addition, one representative vehicle tested in an EPA surveillance program in California was found to have its air pump disabled due to having one of the vacuum control hoses kinked closed. This vehicle was tested as-received (air pump disabled) as well as after having the air pump repaired (vacuum hose unkinked). Data from these four vehicles are listed in the Appendix and summarized in Table 5.

There is some uncertainty as to the HC and CO effects of air pump disablement for non-catalyst vehicles as no similar data are available. However, these vehicles contribute only a very small share of the fleet's emissions over the life of an anti-tampering program. They are assumed to show the same absolute effect due to air pump tampering as for oxidation catalyst vehicles. This assumption is reasonable and due to the small contribution made by these vehicles, does not significantly affect the analysis.

It is assumed that the effects described above apply to all vehicles of the technology type regardless of the emission standards. The available data do not allow a more detailed analysis. It is likely, however, that any error in this assumption is small.

3.2 Catalyst

Automotive catalytic converters lower HC and CO emissions in the exhaust by catalytically promoting the oxidation of HC and CO to harmless by-products. (Catalysts on most 1981 and later vehicles also help reduce NOx emissions.) Catalysts are normally mounted on the underside of the vehicle, along the exhaust pipe and before the muffler; however, a few vehicles have catalysts mounted inside the engine compartment. Tampering with the catalyst usually takes the form of simple removal of the catalyst and replacement with an exhaust pipe. Some automotive parts suppliers carry a complete selection of catalytic converter "test pipes" which can be bolted into the gap left in the exhaust pipe after the converter is removed.

Using carefully placed mirrors or a mirror on an extension, the underside of an inspected vehicle can be examined for the presence of the converter. A catalytic converter is easily distinguished from a muffler since it is made of stainless steel and will not rust. If a catalyst is not observed by checking underneath a 1975 or later model year vehicle, it will be necessary to open the engine compartment hood and either locate the catalyst there or confirm from the emissions label put on every vehicle or from reference literature that the vehicle was not equipped with a catalyst at the factory. Colorado State University has recently published a book which contains this information.[4] Tables 12 through 15 present the percentage of vehicles assumed to have been equipped with a catalyst for this report.

Obviously repair will require installation of a new catalyst (or reinstallation of the old one if it was saved). This could be a relatively expensive repair. New catalysts now cost between $172 and $320. Most of this cost is dealer and distributor markup. However, most vehicles do not require the more expensive converters. A market for lower-priced non-OEM catalysts may also appear, if new OEM catalysts are not a requirement of the program. Some certification of catalyst efficiency should be required before non-OEM catalysts are accepted since the benefits which appear later in this report assume that the replacement catalyst is operating properly. Lower-priced replacement catalysts are possible if enough demand is created by a catalyst check. An average cost of $200 per catalyst has been assumed for this analysis.

The HC and CO emission increases which accompany catalyst removal were determined by examining the engine-out (before the catalyst) emissions of a number of vehicles involved in several test programs. A listing of these vehicles is in the

Appendix. These vehicles received both baseline tests (all components functional) and tests with the catalyst removed or bypassed. By comparing the results of the two tests, the percentage increase in emissions which accompanies catalyst removal can be calculated. Most catalysts are removed with the intent of also using leaded fuel. There is evidence that the use of leaded fuel itself will cause an increase in HC emissions due to lead deposits in the engine. This effect has been ignored in this analysis. Four vehicles with oxidation catalysts and four vehicles with three-way catalysts were tested. The results are summarized in Table 6.

Table 6

Increase in Emissions
Due to Catalytic Converter Removal

Technology	Increase in HC Emissions (gm/mi)	Increase in CO Emissions (gm/mi)	Increase in NOx Emissions (gm/mi)
Oxidation Catalyst	3.05	28.01	0.00
3-way Catalyst	1.68	17.80	2.16

Insufficient testing has been conducted to determine how the effect of catalyst removal varies with the average mileage of a fleet. It is, therefore, assumed that the gram-per-mile increase in emissions from catalyst removal remains the same throughout a vehicle's life, regardless of mileage. This will mean that the percent change due to catalyst removal reduces with increased mileage. This makes sense since very little of the deterioration of the fleetwide emission factor is due to catalyst aging. Most is due to in-use maladjustments and failures of other emission components. Removing the catalyst on a vehicle that has high engine-out emissions can be expected to have a smaller percentage effect than removing a catalyst from a tuned vehicle, since there is usually a relative shortage of oxygen in the exhaust of maladjusted vehicles. This does mean that the estimates will include some degree of uncertainty, especially when applied to high mileage vehicles.

3.3 Habitual Misfueling

The use of leaded gasoline in a vehicle equipped with a catalytic converter, referred to as "misfueling" in this report, will cause a steady contamination of the catalyst material resulting in lower and lower catalytic efficiency. The result of continued misfueling will, therefore, be higher exhaust emission levels as the catalyst loses its ability to convert pollutants into less harmful substances. It has been estimated that after as few as three consecutive tankfuls of leaded fuel, the majority of the catalyst's ability to convert pollutants will be permanently lost, even if the vehicle owner resumes use of unleaded fuel.

Determining the effects of misfueling is more difficult than for most other checks described in this report, since the increase in emissions is heavily dependent on catalyst efficiency and thus the intensity of the misfueling. Misfueling performed sporadically, often referred to as "casual" misfueling, may not permanently destroy the catalyst's function, although there will be some lasting reduction in catalyst efficiency. This section estimates only the effect of habitual misfueling, based on tests of vehicles operated on leaded fuel for many tankfuls. There are insufficient test data to estimate the long term effects of casual misfueling, therefore casual misfueling is assumed to have a comparatively negligible long term effect on fleet emissions.

Even in cases of habitual misfueling, some very low level of catalyst efficiency may still remain. For this reason the effect of misfueling is not as great as removal of the catalyst on an individual basis. Since the overall rate of misfueling is larger than that of catalyst removal, however, the overall effect on emissions is more serious.

EPA has previously estimated the average effect on HC and CO emissions of misfueling. These estimates were used in the mobile source emission factors model (MOBILE2) to adjust the emissions of EPA's essentially misfueling-free emission factors test sample to reflect the extent of misfueling in the fleet as a whole. These estimates were used in the form of a percent increase over the average low-mileage emissions of non-misfueled cars.

In this analysis all data now available were examined to recalculate a gram per mile increase. These data included data from four oxidation catalyst vehicles and seven 1981 and later three-way catalyst vehicles. The emission increases for 1981 and later model year vehicles include any effect misfueling has on oxygen sensor performance in the closed-loop vehicles in the sample. Most vehicles were run on at least 10 tankfuls of leaded fuel. All of the vehicles are listed in the Appendix.

Table 7 presents the estimated effect on emissions as a gram-per-mile increase. As with catalyst removal, the increase expressed in grams per mile is assumed not to change with mileage.

Table 7

Increase in Emissions Due to Misfueling

Technology	Increase in HC Emissions (gm/mi)	Increase in CO Emissions (gm/mi)	Increase in NOx Emissions gm/mi
Oxidation Catalyst	2.47	20.96	0.00
3-way Catalyst	1.57	11.30	0.76

The average cost of replacing a misfueled catalyst will be less than replacing a removed catalyst since in some instances, only the catalytic material within the catalyst need be replaced. Some manufacturers' catalysts have a removable plug for this purpose and provide kits with replacement catalytic material. In this analysis, the average cost for replacing misfueled catalysts is assumed to be $150.

If repair of the fuel inlet restrictor is required, replacement cost of the restrictor will vary substantially. Some vehicles' filler necks can be easily replaced with a new OEM part, while others would require replacement of the entire fuel tank. It is possible to repair the fuel inlet by simply gluing in a metal washer using a gasoline resistant epoxy, however, no credit will be achieved by programs which allow epoxy/washer fixes, because there is no assurance that misfueling would not continue since these washers could be easily inserted and removed. In this analysis the average repair cost for tampered fuel inlet restrictors is assumed to be $80.

As will be discussed in a later section of this report, EPA is concerned that many owners of vehicles with tampered inlets may repair those inlets before submitting to inlet inspection in the first year of a new inlet inspection program, to avoid the costly penalty of catalyst replacement. A State must require that inlets be repaired only with OEM parts and also require the vehicle owner to show proof of purchase and installation of a new or certified catalyst since the purpose of such a program is to require catalyst replacements for misfueled vehicles.

3.4 Positive Crankcase Ventilation System

The positive crankcase ventilation (PCV) system in automobiles provides a means to purge the crankcase of gases escaping from the cylinders by the piston rings. These gases are detrimental to engine life since they dilute and break down engine oil and are corrosive. Originally these gases were vented to the atmosphere, but with the advent of pollution control, these gases have been diverted to the vehicle's intake system for recombustion. The value of the PCV system is well known and established; therefore, its deliberate disablement is relatively rare. Only a small percentage of the vehicles in EPA's surveys had their PCV vacuum hoses disconnected resulting in the blowby gases being released to the atmosphere. Other PCV problems, such as disconnected "fresh air" hoses, also occur but are not believed to cause a significant increase in emissions from the automobile.

Disablement of the PCV system usually takes the form of a disconnected vacuum line or missing components. These disablements are easily identified either visually or by a simple check for vacuum at the fresh air hose. Since all of the components are relatively inexpensive, and since many disablements are simply disconnections, average repair costs are assumed to be $10.

The primary effect of a disabled PCV system is the increase in non-exhaust HC emissions. There are not enough data from recent testing programs on the effects of PCV disablement on current vehicles to determine with complete certainty how much HC emissions would increase. However, it is estimated in MOBILE2 that the average crankcase HC emissions from early 1960's vehicles without PCV systems were about 4.1 gm/mi[5]. At the time, most engines had eight cylinders. It is reasonable to assume that uncontrolled crankcase emissions are proportional to the number of cylinders, so current and future vehicles, which will on average have fewer than eight cylinders, will have proportionately less of an increase when their PCV systems are disabled. Based on this assumption, 6-cylinder engines should have a 3.08 gm/mi effect and 4-cylinder engines a 2.05 gm/mi effect.

To estimate the average effect of PCV disablements, the mix of four, six, and eight cylinder engines in the various model year groups must be determined. Using information on the past and predicted production of vehicles produced in the U.S.[6] and assuming that nearly all imported vehicles are equipped with four cylinder engines, the percent mix of engine sizes can be estimated for each model year group. These values were used to combine the estimates for crankcase

HC emissions from each engine size to determine an overall figure for each model year group. These overall figures are presented in Table 8.

Table 8

Increase in HC Emissions Due to PCV Disablement

	Increase in HC Emissions (gm/mi)	
Model Years	LDV & LDT1	LDT2
Pre-1963	-	-
1963-1968	3.80	-
1968-1970	3.74	5.20
1971-1974	3.51	4.88
1975-1977	3.44	4.78
1978-1979	3.29	4.57
1980	2.83	3.93
1981-1982	2.68	3.73
1983 and Later	2.49	3.46

As shown in Table 15 at the end of this section, all 1968 and later vehicles are assumed to be equipped with PCV systems. Between 1963 and 1968 another system was used to vent crankcase emissions into the air cleaner of most vehicles. These systems have no PCV valves or vacuum hoses, yet they were fairly effective in controlling crankcase emissions. It is therefore likely that, contrary to the assumption used in this report, a disablement of a PCV system which leaves the hose connection to the air cleaner intact, will not return the vehicle's crankcase emission levels to those of an uncontrolled vehicle. Also, the emission estimates of an uncontrolled vehicle assume a continuous evacuation of the crankcase using a vent tube. Even a disablement of a PCV system that interferes with both the vacuum hose to the carbureter and the fresh air hose to the air cleaner will not cause a continuous evacuation of the crankcase to the atmosphere. For these reasons, the estimates in the report for excess emissions from PCV disablements may be overstated. Since the PCV tampering rates are fairly low, this is not a major concern to EPA. EPA is planning a test program to better determine the effect of PCV system tampering.

3.5 Evaporative Emission Control System

The evaporative control system is intended to capture the gasoline fumes which are naturally given off whenever gasoline is stored and used. These fumes are made up of pure hydrocarbon (HC) emissions and represent a significant portion of a vehicle's total HC emissions. The evaporative control system captures the fumes given off by both gasoline in the fuel tank and the gasoline in the carburetor (early systems dealt only with evaporative losses from the fuel tank). These fumes are stored in a charcoal canister, usually mounted in the engine compartment, and then routed to the engine for burning at appropriate times.

Disablement can take the form of disconnected or cut hoses, missing canisters, or removal of the entire system. Once again, these forms of disablement are identifiable by trained inspectors. A quick visual check can usually determine whether the canister is still intact and if all the hoses are attached to it. An average repair cost of $10 has been assumed since most repairs will involve simply reconnection of hoses.

The emission increases assigned to each grouping to represent a tampered system come from MOBILE2. The passenger car model year groupings used in MOBILE2 are: pre-1970, 1970-1971, 1972-1974, 1975-1977, 1978-1980, 1981 and later. The assumption used to determine the increase in emissions due to evaporative system disablement for pre-1977 vehicles was that any disablement would return the vehicle to uncontrolled levels (pre-1970) of evaporative HC. This assumption is necessary since there has been no disablement testing done for evaporative control systems on these older vehicles. These vehicles are similar, however, in size and design to the pre-controlled vehicles so that the error should be small. Newer vehicles have smaller carburetors and gas tanks and, therefore, should emit less evaporative emissions even if tampered.

Two 1981 model year vehicles have been tested with and without disabled evaporative canisters. These vehicles are listed in the Appendix. As expected the average evaporative emissions with the evaporative canister disconnected were less than for pre-controlled vehicles. Since downsizing for passenger cars began with the 1977 model year and leveled off after the 1980 model year, the uncontrolled emission levels for those model years were interpolated between the evaporative emission levels of pre-1970 vehicles and the test results from the 1981 vehicles. The resultant increases in evaporative HC emissions due to disablement of the evaporative control system are tabulated in Table 9. These increases were derived from vehicle testing with Indolene, the fuel used in EPA's certification program. The effect of canister disconnection where commerical fuel with higher volatility is sed is not known at this time.

Table 9

Increase in HC Emissions Due To Evaporative System Disablement

Model Years	Increase in Evaporative HC Emissions (gm/mi)		
	Passenger Cars	Light-Duty Trucks (0-6000 lbs)	Light-Duty Trucks (6000-8500 lbs)
1971	0.69	0.81	-
1972-1976	1.18	1.39	-
1977	1.01	1.39	-
1978	1.70	2.41	-
1979	1.53	2.41	1.88
1980	1.36	2.41	1.88
1981 and Later	1.50	2.58	2.01

Because of different assumptions for average mileage traveled per day and uncontrolled evaporative emission levels for light-duty trucks, the increases in evaporative emissions for these vehicles are somewhat different than for passenger cars. Most light-duty trucks over 6000 pounds built before the 1979 model year were not equipped with evaporative control systems other than the PCV system. The increase in evaporative emissions for light-duty trucks also assumes no downsizing.

3.6 Light-Duty Truck Effects

In MOBILE2 light-duty vehicles (passenger cars) are treated separately from light-duty trucks. In fact, MOBILE2 divides light-duty trucks into two groups, those less than 6,000 lbs gross vehicle weight (LDT1) and those between 6,000 and 8,500 lbs GVW (LDT2). Since light-duty trucks make up a significantly smaller portion of the vehicle fleet than passenger cars, less is known about the occurrence and effects of tampering on these vehicles than on passenger cars.

Since the emission standards applicable to light-duty trucks (LDTs) in a given calendar year are often quite different from passenger cars, it can be expected that emission control devices used on LDTs, such as air pumps and catalysts, will differ in a given calendar year from those on passenger cars. However, as the emission and fuel economy standards for light-duty trucks become more and more stringent, these vehicles will closely resemble passenger cars with similar emission standards. Tables 12 through 15 present the assumptions used in this report regarding the number of light-duty trucks equipped with various emission control components. These estimates were taken from EPA's emission factor samples where adequate samples were available.

In general, the per-vehicle emission benefits estimated for passenger cars have been used for light-duty trucks using the same emission control components. The primary differences will be in the model years using a particular estimated benefit. For example, only the 1979 and later LDT2s are assumed to have been equipped with catalysts and therefore would receive emission benefits from a catalyst inspection program.

3.7 Oxygen Sensor Check

Many passenger vehicles beginning with the 1981 model year utilize a computer to control vehicle engine parameters and to optimize performance, economy and emissions under variable operating conditions. The key to the proper operation of these systems is the ability of the computer to accurately sense the engine performance and operating conditions and then alter the engine parameters to improve engine performance. These systems are often referred to as "closed-loop" systems. Early versions of these systems were used in California vehicles as early as 1978. Table 10 estimates the number of these closed-loop systems in the 1981 and 1982 federal fleet from the EPA Emission Factor Sample.

Table 10

Model Year	Percent of Passenger Vehicles Equipped With Closed-Loop Systems
1981	65.3%
1982	57.0%

Since these systems depend upon accurate sensing of engine performance and operating conditions, malfunction of sensing devices can cause the computer to incorrectly set engine parameters or revert to default operating modes. Both of these conditions can cause large increases in all three regulated pollutants and substantial loss of fuel economy.

In particular, closed-loop vehicles require precise control of the air/fuel mixture to optimize the operation of the three-way catalyst used on these cars. Too much oxygen in the exhaust impedes NOx control and not enough oxygen leads to loss of HC and CO control. Therefore, an important sensing device for controlling HC, CO and NOx emissions is the oxygen sensor, which can sense the amount of unreacted oxygen in the engine exhaust. Malfunction or disconnection of the oxygen sensor will cause partial or complete loss of computer control of the air/fuel mixture. In some vehicles, this causes very high emissions.

EPA has conducted tests on 20 closed-loop vehicles which have had the oxygen sensor disabled or with the oxygen sensor leads grounded in the laboratory, to determine the effect of this disablement on emissions. The average increase in HC and CO and NOx emissions is presented in Table 11.

Table 11

Increase in HC, CO and NOx Emissions Due to Oxygen Sensor Disablement

Model Years	Increase in HC Emissions (gm/mi)	Increase in CO Emissions (gm/mi)	Increase in NOx Emissions (gm/mi)
1981 and Later Closed-Loop Vehicles	1.38	45.08	0.01

Many vehicles with disabled or malfunctioning oxygen sensors causing high FTP emissions of HC and CO will fail the idle test portion of an I/M inspection. In the EPA study, 45% of closed-loop vehicles with deliberately disabled oxygen sensors were correctly identified by a simple idle test. However, these vehicles accounted for over 80% of the excess HC and CO emissions from those tests. The other 55% of disabled vehicles did not respond to the disablement with particularly high emissions, so identifying them is less important. A two-speed idle test or a loaded-mode test does even better. Thus it may be appropriate to take credit for only 20% of the excess emissions as calculated in Table 11 when an oxygen sensor check is added to an I/M program. This percentage would vary depending on the individual program's cutpoints.

Disablement of the oxygen sensor directly affects the vehicle's air/fuel mixture and can readily be detected in most important cases by an idle test. For this reason the oxygen sensor check will be most useful for an in-use emission control program which checks for tampering as part of an established saftey inspection or one which does not use an idle or other exhaust test. For example, a program surveying large commercial fleets for tampering might find an oxygen sensor check worthwhile. Also, an oxygen sensor check would be a useful element in a tampering check to determine eligibility for a repair cost waiver in I/M programs which give waivers only to untampered vehicles.

Since these closed-loop systems are relatively new to the vehicle owning public and since they have only been in widespread use for a few years, it is difficult to judge with any certainty how vehicles owners will react to these systems. Because disablement of the oxygen sensor will often cause a loss in fuel economy, knowledgeable car owners would be unlikely to deliberately disconnect it. However, disconnections may occur inadvertently or because of misperceptions.

Replacement costs for new oxygen sensors are high enough that some vehicle owners may disconnect a faulty sensor rather than incur the cost of replacement. Any faulty oxygen sensors which were left properly connected would easily pass a visual inspection. In most of the important cases, the idle test portion of the I/M inspection will identify the vehicle as needing repair.

Vehicles made by General Motors which have on-board self-diagnostic routines within the computer system will cause a dashboard trouble light to come on if there are serious engine problems such as a defective oxygen sensor. This trouble light could be checked on all GM vehicles as part of the underhood inspection to detect properly connected, but defective, oxygen sensors. Because the trouble light on the dashboard can turn back off at times even with a defective oxygen sensor, a more reliable check would be to test the GM computer system for "trouble codes", which are more permanently stored. This check is more complicated than a visual inspection, but may still be practical depending on local circumstances.

There is little knowledge as to the rate at which oxygen sensors will be disabled. Past tampering surveys did not check this component. The FY83 survey did look for oxygen sensor disablements, but the results are not yet available. It is not expected that enough observations could have been made anyway to determine an appropriate rate of occurrence. In the EPA Emission Factor database, only one of nearly 800 closed-loop vehicles tested had a disabled oxygen sensor and none had dashboard "check-engine" lights indicating trouble, although some vehicles had stored self-diagnostic trouble codes indicating problems with the oxygen sensor. In the absence of survey data, then, one must speculate that the rate of disablement will be small, probably less than 1%.

Replacement of a defective or missing oxygen sensor can be fairly expensive. An oxygen sensor for a typical General Motors closed-loop vehicle will cost about $50. Most disablements, however, will involve simple disconnection of the wiring to the sensor. Repair will simply mean reconnection of the sensor. Faulty oxygen sensors will either not be detected by the visual inspection or will be covered by the vehicle's emission warranties for vehicles with less than 50,000 miles.

Table 12

Estimates of Technology Mix for Passenger Cars

Model Year	Percent Air Pump & No Catalyst	Percent Catalyst & Air Pump	Percent Catalyst & No Air Pump	Percent EGR & No 3-Way Catalyst	Percent EGR & 3-Way Catalyst	Percent 3-Way Catalyst & No EGR
Pre-1968	-	-	-	-	-	-
1968	5	-	-	-	-	-
1969	5	-	-	-	-	-
1970	5	-	-	-	-	-
1971	5	-	-	-	-	-
1972	10	-	-	-	-	-
1973	30	-	-	80	-	-
1974	30	-	-	90	-	-
1975	15	30	50	90	-	-
1976	10	30	55	90	-	-
1977	10	20	65	90	-	-
1978	5	25	65	90	-	-
1979	5	25	65	90	-	-
1980	-	65	30	90	7	-
1981	-	85	15	5	85	2
1982	-	70	30	5	85	2
1983	-	60	40	5	85	2
1984	-	60	40	-	93	7
1985	-	40	60	-	93	7
1986	-	40	60	-	93	7
1987&Later	-	30	70	-	90	10

Table 13

Estimates of Technology Mix for Light-Duty Trucks Less Than 6,000 lbs. GVW

Model Year	Percent Air Pump & No Catalyst	Percent Catalyst & Air Pump	Percent Catalyst & No Air Pump	Percent EGR & No 3-Way Catalyst	Percent EGR & 3-Way Catalyst	Percent 3-Way Catalyst & No EGR
Pre-1968	-	-	-	-	-	-
1968	5	-	-	-	-	-
1969	5	-	-	-	-	-
1970	5	-	-	-	-	-
1971	5	-	-	-	-	-
1972	10	-	-	-	-	-
1973	30	-	-	80	-	-
1974	30	-	-	90	-	-
1975	10	30	30	90	-	-
1976	10	30	30	90	-	-
1977	10	20	55	90	-	-
1978	10	20	55	90	-	-
1979	10	40	45	100	-	-
1980	10	40	45	100	-	-
1981	-	50	50	100	-	-
1982	-	50	50	90	10	-
1983	-	50	50	80	20	-
1984	-	50	50	60	40	-
1985	-	50	50	60	40	-
1986	-	50	50	60	40	-
1987&Later	-	50	50	15	85	-

Table 14

Estimates of Technology Mix for Light-Duty Trucks Between 6,000 and 8,500 lbs. GVW

Model Year	Percent Air Pump & No Catalyst	Percent Catalyst & Air Pump	Percent Catalyst & No Air Pump	Percent EGR & No 3-Way Catalyst	Percent EGR & 3-Way Catalyst	Percent 3-Way Catalyst & No EGR
Pre-1968	-	-	-	-	-	-
1968	-	-	-	-	-	-
1969	-	-	-	-	-	-
1970	-	-	-	-	-	-
1971	-	-	-	-	-	-
1972	-	-	-	-	-	-
1973	-	-	-	30	-	-
1974	-	-	-	30	-	-
1975	-	-	-	30	-	-
1976	-	-	-	30	-	-
1977	-	-	-	30	-	-
1978	-	-	-	30	-	-
1979	-	50	50	100	-	-
1980	-	50	50	100	-	-
1981	-	50	50	100	-	-
1982	-	50	50	100	-	-
1983	-	50	50	100	-	-
1984	-	50	50	60	40	-
1985	-	50	50	60	40	-
1986	-	50	50	60	40	-
1987&Later	-	50	50	15	85	-

Table 15

Estimate of Percentages of Vehicles
Equipped with PCV and Evaporative Control Systems

Model Year Group	Percent LDV		Percent LDT1		Percent LDT2	
	PCV	Evap	PCV	Evap	PCV	Evap
Pre-1968	-	-	-	-	-	-
1968-1970	100	-	100	-	100	-
1971-1978	100	100	100	100	100	-
1978 & Later	100	100	100	100	100	100

4.0 METHOD FOR CALCULATION OF HC AND CO BENEFITS OF ANTI-TAMPERING AND ANTI-MISFUELING PROGRAMS

This section describes in general how benefits presented in Section 5.0 are calculated. Specific assumptions made in calculating the benefits are stated and explained in Section 5.0. However, the explanations there depend on the framework presented in this section.

This section also presents the additional, or excess, emissions caused by tampering and misfueling in the absence of any special programs to reduce them. The purpose of doing so is to illustrate the size of the problem to be addressed by an anti-tampering or anti-misfueling program. This section also illustrates the relative importance of different forms of tampering. Section 5.0 presents estimates of how much emission reduction is possible from different types of programs.

4.1 Discussion of Method

The approach used in this report begins with a single model year's vehicles. The calculation described below is performed for each of the last 19 model years, resulting in a total emissions impact for each from all forms of tampering combined. These 19 model year-specific impacts are then added using age-based vehicle miles traveled (VMT) fractions as weighting factors to arrive at the impact on the composite emissions of, for example, passenger cars of all ages.

The description below assumes passenger cars, but the same procedure is used for light-duty trucks.

The calculation consists of the following steps for each model year:

(A) Separate the model year into subgroups with distinct combinations of equipment, such that all cars in a subgroup are susceptible to the same types of tampering. Specifically, cars with air pumps and catalysts must be separated from cars with only air pumps and cars with only catalysts, since simultaneous air pump and catalyt tampering is possible for one subgroup but not the others. The sales fraction for each of these subgroups must be known; the necessary fractions were given in Section 3.0. Because in a single model year all cars either have or do not have PCV and evaporative controls, and because the impacts of PCV and evaporative tampering are strictly additive to the impacts of misfueling, catalyst removal, and air pump disablement, there is no need to define subgroups based on PCV and evaporative equipment.

(B) Identify all the unique combinations of tampering that can occur on cars in each subgroup. These are as follows:

Air Pump/Catalyst	Catalyst Only	Air Pump Only
1) Air Pump/Catalyst		
2) Air Pump/Misfueling(Inlet)		
3) Air Pump/Misfueling(Other)		
4) Air Pump/Catalyst/Misfueling(Inlet)		
5) Air Pump/Catalyst/Misfueling(Other)		
6) Catalyst/Misfueling(Inlet)	X	
7) Catalyst/Misfueling(Other)	X	
8) Air Pump Only		X
9) Catalyst Only	X	
10) Misfueling(Inlet) Only	X	
11) Misfueling(Other) only	X	

In the above list, "(Inlet)" designates habitual misfueling accompanied by tampering of the inlet restrictor. "(Other)" designates habitual misfueling accomplished by other means, such as a small pump nozzle or a funnel. As before, PCV and evaporative tampering can be kept separate.

(C) Find the percentage of vehicles with each of the above unique combinations of tampering on the evaluation date assuming no special program to reduce tampering and misfueling. Since the tampering rates derived in Section 2.0 depend on mileage, the odometer of the model year on the evaluation date (always a January 1) must be known. This report uses the same values for this odometer variable as does the draft version of MOBILE3. Anti-tampering programs will be evaluated by EPA using the final version of MOBILE3. Mileage accumulation rates and other parameters of the model used in this report are subject to change. Given an odometer value, the equations from Section 2.0 can be used to calculate the overall air pump rate (AIR), catalyst removal rate (CAT), the rate of misfueling via inlet tampering (INLET), and the rate of misfueling via other means (OTHER). These overall tampering rates are the sum of the rates for two or more of the above unique combinations of tampering. To calculate the individual rate for each unique combination, additional assumptions are necessary. To fill this need, EPA has had to assume that the rate for a given overlap combination is always proportional to the overall rate of one or the other of the forms of tampering that make up the overlap combination.

For example, EPA has had to assume that the rate of simultaneous air pump and catalyst tampering is 6.6% of the overall air pump tampering rate, regardless of any local variation in overall air pump tampering rate or overall catalyst tampering rate. (The figure of 6.6% was determined from the 1982 Tampering Survey data.) An exception is made if necessary to prevent a logical contradiction; in the example given, the rate of simultaneous air pump and catalyst tampering is never assumed to be larger than the overall rate of catalyst or air pump tampering determined from Section 2.0. Similar assumptions are made for other overlap combinations. The full set of assumptions is as follows:

Rate (1) = .066 x AIR
Rate (2) = .111 x AIR
Rate (3) = .105 x AIR
Rate (4) = .238 x CAT
Rate (5) = .032 x CAT
Rate (6) = .441 x CAT
Rate (7) = .050 x CAT
Rate (8) = AIR - [Rate(1)+Rate(2)+Rate(3)+Rate(4)+Rate(5)]
Rate (9) = CAT - [Rate(1)+Rate(4)+Rate(5)+Rate(6)+Rate(7)]
Rate (10) = INLET - [Rate(2)+Rate(4)+Rate(6)]
Rate (11) = OTHER - [Rate(3)+Rate(5)+Rate(7)]

As mentioned, alterations are made as necessary to prevent logical contradictions that would otherwise result in one or more of the last four rates being negative. PCV and evaporative tampering rates come directly from the equations in Section 2.0.

(D) Find the percentage of vehicles which had each of the unique combinations of tampering on the day the anti-tampering/anti-misfueling program being analyzed began. This information is needed for step E below. It is calculated in the same way as in the previous step, but with appropriately lower odometer and hence lower tampering rates.

(E) Determine the tampering rate for each unique combination of tampering, this time assuming a specific anti-tampering/anti-misfueling program is in operation. This requires the information developed in steps C and D, and assumptions regarding the effectiveness of the specific program being analyzed. The assumptions used in this step are stated and explained in Section 5.0. A simple hypothetical assumption might be that in a program that inspects only for catalyst presence, 95% of further catalyst removal ceases, 95% of missing catalysts are replaced, but no other tampering is corrected. Mathematically, this can be expressed as follows:

(Tampering Rate With Program) =
f(Tampering Rates Without Program)

or,

With Program Without Program
Rate (1) = 0.05 Rate (1)
Rate (2) = Rate(2)+ 0.95 Rate(4)
Rate (3) = Rate(3)+ 0.95 Rate(5)
Rate (4) = 0.05 Rate (4)
Rate (5) = 0.05 Rate (5)
Rate (6) = 0.05 Rate (6)
Rate (7) = 0.05 Rate (7)
Rate (8) = Rate(8)+ 0.95 Rate(1)
Rate (9) = 0.05 Rate (9)
Rate (10) = Rate(10)+ 0.95 Rate(6)
Rate (11) = Rate(11)+ 0.95 Rate(7)

Where the new rates on the left are with the catalyst check program and the old rates on the right are from step C. The equations express the fact that most vehicles which formerly suffered from catalyst removal and another form of tampering now suffer only from the other form since the missing catalyst is replaced.

In this example, the tampering rates with the catalyst inspection program depend only on the "without" rates on the evaluation date, i.e., the results of step C.

For some program types, the tampering rate with a program depends on the results of both steps C and D. In the hypothetical example, deterrence of catalyst removal might have been assumed more effective than replacement of already missing catalysts. The catalyst removal rate with the program would then depend on the level of removal when the program started, step D.

As before, PCV and evaporative tampering are kept separate.

(F) Assign each unique combination of tampering an emissions impact per vehicle. The impacts are taken from Section 3.0, with the following further assumptions regarding cases of simultaneous tampering.

- The impact of simultaneous catalyst removal and either or both of misfueling or air pump tampering is the same as stated in Section 3.0 for catalyst removal alone.
- The impact of simultaneous misfueling and air pump tampering is the same as stated in Section 3.0 for misfueling above.

(G) Multiply tampering rate by tampering impact for each unique combination, and add the result for all combinations taking into account the sales split between the air pump only subgroup, the air pump/catalyst-equipped subgroup and the catalyst-only subgroup. Add to this the rate-times-impact result for PCV and evaporative tampering. The sum is the excess emissions due to the tampering and misfueling that remain despite the operation of the anti-tampering/anti-misfueling program being analyzed.

(H) Repeat the calculation skipping step E, i.e., assuming no program in operation. This gives the excess emissions in the absence of any special program.

(I) Subtract the result of step G from that of step H. The difference is the benefit of the program for the one model year in question.

Composite excess emissions and the composite benefit can be calculated by weighting each model year by its age based VMT fraction, also known as its travel fraction. This can be done at steps G and H or at step I, depending on the desired outcome.

The method described above assumes that the user of the result of the calculation is interested in a situation in which vehicles are driven under standard conditions of temperature, speed, etc. All of the benefits shown in this document assume such a situation as well. It is possible to analyze other situations if correction factors for non-standard conditions are applied at an appropriate step in the calculation. EPA's forthcoming computer program MOBILE3 will have this capability, although in the standard version of MOBILE3 step E above will be bypassed. Users interested in performing calculations with MOBILE3 which would require step E should contact EPA.

The method described above applies for both I/M and non-I/M areas, provided either I/M or non-I/M tampering rates are used consistently.

The reader should note that in contrast to MOBILE3, its predecessor MOBILE2 does not internally calculate excess emissions from tampering and misfueling, with or without a program to control them. MOBILE2 calculates only a single estimate of in-use emissions and does not identify which portion is attributable to tampering and misfueling. The analysis behind MOBILE2 did explicitly account for and identify some but not all of what is now recognized as the effect of tampering and misfueling, and the data base used to develop MOBILE2 implicitly accounts for some further but unknown and unidentifiable portion of the actual effect. Consequently, consistent and reliable analysis of the effects of tampering and misfueling and programs to reduce them are only possible with MOBILE3. Until MOBILE3 is available, one may assume that MOBILE2's predictions of in-use emissions is correct, and may subtract from the MOBILE2 estimate the appropriate program benefits shown in this report to arrive at an estimate of in-use emissions with a tampering/misfueling control program. Once MOBILE3 is available, it must be used (by itself with EPA assistance or in conjunction with the pre-calculated benefits in this report) unless it can be shown that use of MOBILE3 would cause unreasonable delays in analysis and adoption of air quality improvement measures.

4.2 Example Calculation

4.2.1 One Model Year

This example will calculate the excess emissions due to tampering and misfueling for the 1977 model year. We will assume that the vehicles are located in a non-I/M area, and we will use the national average tampering and misfueling rates described in Section 2.0. In order to show how an anti-tampering program affects the excess emissions, we will assume that an annual catalyst presence inspection began on January 1, 1984. We will evaluate all excess emissions for January 1, 1988.

On average, the 1977 model year is estimated to have accumulated 76,998 miles by January 1, 1984 and 105,156 miles by January 1, 1988. Using these mileages and the rate equations from Section 2.0 the overall rates of tampering and misfueling can be estimated. These are presented in Table 16.

Table 16

Example Calculation of Tampering and Misefuling Rates

	Non-I/M Area LDV Rate Equations (Percent)		Rate at	Rate at
System	Zero-Mile Level	Increase/10K miles	Program Start (76,998 miles)	Evaluation (105,156 miles)
Air Pump	-2.71	2.652	.177	.252
Catalyst	-1.75	1.611	.105	.150
Fuel Inlet	-1.43	2.022	.141	.198
Other Misfueling	1.65	0.559	.060	.075
PCV	0.02	0.248	.019	.026
Evaporative	-0.48	0.335	.021	.030

As outlined in Section 4.1, these overall rates are used to estimate the size of the 11 overlap categories. Category 12 represents untampered vehicles. These categories do not include PCV and evaporative canister tampering, which are addressed later in this Subsection. For HC and CO excess emissions there are three technology types of interest; air pump only, catalyst only and air pump with catalyst.

Vehicles with air pumps but without catalysts have no overlaps and, therefore, have the air pump tampering rate in air pump only (tampering category 8), and zero rates in all other categories. This could also be done by adding categories 1 through 5 to category 8 and categories 6, 7, 9, 10 and 11 are added to category 12 (no tampering or misfueling). The categories are eliminated and their rates shifted to other categories in order to remove categories which cannot occur with the given technology type. For example, category 1 represents vehicles with disabled air pumps and missing catalysts. If we are analyzing vehicles equipped with air pumps and without catalysts, this category is meaningless. To correctly account for all air pump disablement, however, the vehicle rate assigned to category 1 must be added to category 8 (air pump disablement only). Vehicles with catalysts, but without air pumps, have zero rates in categories 1 through 5 and category 8 since these require the possibility of air pump tampering. The rates in categories 1, 2, 3, 4, 5, and 8 are added to categories 9, 10, 11, 6, 7, and 12 respectively. Vehicles with air pumps and catalysts have rates in all 11 categories. Using the equations described in Section 4.1(C) and (E) and rates estimated in Table 16 the 11 category sizes can be determined. These are presented in Table 17. The category sizes for air pump only and catalyst only vehicles can be derived from the rates in Table 17.

Table 17

Example Calculation of Overlap Categories (Catalyst vehicle equipped with air pumps only)

Overlap Category	Category Description*	Equation	Category Size At Program Start	 At Evaluation
(1)	AIR/CAT	.066*AIR	.0117	.0166
(2)	AIR/NCK	.111*AIR	.0196	.0280
(3)	AIR/OTHR	.105*AIR	.0186	.0265
(4)	AIR/CAT/NCK	.238*CAT	.0250	.0357
(5)	AIR/CAT/OTHR	.032*CAT	.0034	.0048
(6)	CAT/NCK	.441*CAT	.0463	.0662
(7)	CAT/OTHR	.050*CAT	.0053	.0075
(8)	AIR	AIR-(1-5)	.0987	.1404
(9)	CAT	CAT-(1,4,5,6,7)	.0133	.0192
(10)	NCK	NCK-(2,4,6)	.0501	.0681
(11)	OTHR	OTHR-(3,5,7)	.0327	.0362

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* AIR: Air Pump Disabled
CAT: Catalyst Removed
NCK: Misfueling by Enlarging Fuel Filler Inlet
OTHR: Other Misfueling

The excess emissions from this model year without the program can be estimated from the evaluation date estimates of tampering and misfueling rates from Table 17. First, the emission impact of each of the categories must be determined. Since all of the 1977 model year uses oxidation catalyst technology, the emission impact of air pump disablement, catalyst removal and misfueling can be taken directly from the appropriate tables in Section 3.0. For simplicity only total HC emissions will be addressed in this example. It is assumed that the effect of catalyst removal supercedes all other tampering and misfueling effects, therefore the overlap categories 1, 4, 5, 6, 7, and 9 which all contain catayst removal would experience the emission impact of catalyst removal. The effect of misfueling is assumed to supercede the emission impact of air pump disablement. The overlap categories 2, 3, 10, and 11 which all contain misfueling but without catalyst removal would experience the emission impact of misfueling. Only category 8, which contains only air pump disablements experiences the air pump disablement emission impact. These emission impact groups are summed in Table 18.

The excess emissions due to tampering and misfueling are determined by multiplying the size of each emission impact group times the appropriate excess emission estimate from Section 3.0. The three technology types are then weighted by their fleet fractions also from Section 3.0 and summed for the combined excess emissions from air pump, catalyst, and misfueling. This calculation is presented in Table 18.

Table 18

Example Calculation of Emission Impact

Technology Type	Emission Impact Groups	Overlap Categories	(A) Emission Impact Group Size	(B) Excess Total HC Emissions (gm/mi)	(C) Technology Fleet Fraction	Composite Emission Impact (A)*(B)*(C)
Air Pump With Catalyst	Air Pump Disabled	(8)	.1404	1.37	.20	.038
	Catalyst Removed	(1,4,5,6,7,9)	.1500	3.05	.20	.092
	Misfueled	(2,3,10,11)	.1588	2.47	.20	.078
Air Pump Only	Air Pump Disabled	(1-5,8)	.2520	1.37	.10	.035
Catalyst Only	Catalyst Removed	(1,4-7,9)	.1500	3.05	.55	.252
	Misfueled	(2,3,10,11)	.1588	2.47	.55	.216
			Total Emission Impact			0.71 gm/mi

PCV and evaporative canister tampering effects are assumed not to overlap with any of the other tampering and misfueling. As a result the excess emissions due to these types of tampering can be determined by simply multiplying together the evaluation date rate estimated from Table 16 and the appropriate excess emissions and technology type fleet fraction from Section 3.0. This calculation is presented in Table 19.

Table 19

Example Calculation of Excess Emission from PCV and Evaporative Canister Disablements

System	(A) Tampering Rate Fraction	(B) Excess Total HC Emissions (gm/mi)	(C) Technology Fleet Size Factor	Composite Emission Impact (A)*(B)*(C)
PCV	.026	3.44	1.0	.089
Evap	.030	1.01	1.0	.030
			Total Emissions Impact	.012 gm/mi

The effect of an annual catalyst presence inspection is estimated by reducing the size of the appropriate overlap category sizes to reflect assumptions about how effective the program would be in reducing catalyst removal. In the hypothetical case of Section 4.1, 95% of catalyst removals which occurred previous and would occur subsequent to the start of the inspection program are assumed to be replaced or deterred from occurring. Later sections will examine the issue of program effectiveness in more detail. The effectiveness of a catalyst inspection program used in the example will be the 95% assumed in later sections.

In some cases the effectiveness of an inspection program will differ depending on whether the tampering and misfueling occurs before or after the program begins. This is because, in some cases, it can be assumed that a program will be more effective in deterring tampering and misfueling which has not yet occurred, than it can be in detecting and permanently correcting tampered or misfueled vehicles. As a result two sets of overlap categories representing tampering and misfueling which occurred before and after the program start must be calculated. The "previous" category sizes are the category sizes at the program start. The "subsequent" category sizes can be calculated by subtracting the "previous" category sizes from the category sizes at the evaluation date. The previous and subsequent overlap category sizes are presented in Table 20.

Table 20

Example Calculation of
Previous and Subsequent Tampering
and Misfueling Category Sizes

Overlap Category*	(A) Previous Rates (At Program Start)	(B) Rates at Evaluation	Subsequent Rates [(A) - (B)]
(1)	.0117	.0166	.0049
(2)	.0196	.0280	.0084
(3)	.0186	.0265	.0079
(4)	.0250	.0357	.0107
(5)	.0034	.0048	.0014
(6)	.0463	.0662	.0199
(7)	.0053	.0075	.0022
(8)	.0987	.1404	.0417
(9)	.0133	.0192	.0059
(10)	.0501	.0681	.0180
(11)	.0327	.0362	.0035

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*See Table 17 for description.

Since in this example the effect of the inspection program on previous and subsequent tampering and misfueling rates is identical, for simplicity the example will apply the effectiveness factors to the sum of the previous and subsequent rates. Normally two separate calculations are required.

As described in Section 4.1(E), if the catalyst inspection program is assumed to be 95% effective, then categories 1, 4, 5, 6, 7, and 9 must all be reduced to 0.05 of their previous sizes. However, since no other tampering or misfueling is affected by the inspection program, 95% of the rates in categories 1, 4, 5, 6, and 7 are added to categories 8, 2, 3, 10, and 11 respectively. This process is shown in Table 21.

Table 21

Example Calculation of Resultant Category Sizes With an Annual Inspection Program

Resultant Category*	Overlap Category Adjustment	Resultant Category Size
(1)	.05 * (1)	.0008
(2)	(2) + .95 * (4)	.0619
(3)	(3) + .95 * (5)	.0311
(4)	.05 * (4)	.0018
(5)	.05 * (5)	.0002
(6)	.05 * (6)	.0033
(7)	.05 * (7)	.0004
(8)	(8)	.1404
(9)	.05 * (9)	.0010
(10)	(10) + .95 * (6)	.1310
(11)	(11) + .95 * (7)	.0433

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*See Table 17 for descriptions.

Once the category sizes have been adjusted to reflect the inspection program, the previous and subsequent categories can be added together, grouped by emission impact, and multiplied by the excess emissions estimated for each group, as was done to estimate the excess emissions without the program in Table 18. This process is shown in Table 22.

Table 22

Example Calculation of Emission Impact With an Annual Catalyst Inspection Program

Technology Type	Emission Impact Groups	Overlap Categories	(A) Emission Impact Group Size	(B) Excess Total HC Emissions (gm/mi)	(C) Technology Fleet Fraction	Composite Emission Impact (A)*(B)*(C)
Air Pump With Catalyst	Air Pump Disabled	(8)	.1404	1.37	.20	.038
	Catalyst Removed	(1,4-7,9)	.0075	3.05	.20	.005
	Misfueled	(2,3,10,11)	.2673	2.47	.20	.132
Air Pump Only	Air Pump Disabled	(1-5,8)	.2520	1.37	.10	.035
Catalyst Only	Catalyst Removed	(1,4-7,9)	.0075	3.05	.55	.013
	Misfueled	(2,3,10,11)	.2673	2.47	.55	.363
			Total Emission Impact			0.59 g/mi

Table 23 compares the excess emissions from this single model year with and without the catalyst presence inspection program. This process is done for each model year and weighted together by the vehicle mileage fraction contributed by each model year to the fleet mileage accumulation to give a composite excess emission estimate. This is shown in the next Subsection.

Table 23

Comparison of Excess Emissions With and Without an Annual Catalyst Inspection Program

	Excess Emissions (gm/mi)	
	Without Program	With Program
Excess Emissions from Air Pump Disablement, Catalyst Removal and Misfueling	0.71	0.59
Excess Emissions from PCV and Evaporative Canister Disablements	0.12	0.12
Total Excess Emissions	0.83 gm/mi	0.71 gm/mi

4.2.2 Composite of All Model Years

Once an estimate of the excess emission due to tampering and misfueling has been made for each of the last 19 model years, these estimates are weighted together by the vehicle mileage fraction contribution of each model year to the fleet mileage accumulation. The sum of the weighted excess estimates then the composite vehicle excess emissions with and without an inspection program. The difference between these sums the emission reductions which can be attributed to the program. Table 24 is an example of the calculation of the program benefit of inspection for catalyst presence on all 1975 and later vehicles.

4.3 Emissions Due to Tampering and Misfueling: All Types

Tables 25 and 26 present the estimates of excess emissions on January 1, 1988, due to all forms of tampering and habitual misfueling using the estimates of tampering and misfueling rates as discussed in Section 2.0 and the increases in emissions due to tampering and misfueling from Section 3.0.

Table 24

Example Calculation of Composite Emissions Benefit From All Model Years*

	(a)	(b)	(c)	(a)[(b)-(c)]
	VMT Fraction	Excess Emissions (gm/mi)		Emission Reduction
Model Year	in Evaluation Year (1/1/88)	Without Program	With Catalyst Inspection Program	Due to Inspection Program
1970	.001	1.33	1.13	.00020
1971	.001	1.26	1.07	.00019
1972	.003	1.19	1.01	.00054
1973	.007	1.12	0.95	.00119
1974	.011	1.05	0.89	.00176
1975	.018	0.98	0.83	.00270
1976	.025	0.90	0.77	.00325
1977	.031	0.83	0.71	.00372
1978	.045	0.75	0.64	.00495
1979	.057	0.67	0.58	.00513
1980	.067	0.60	0.51	.00603
1981	.075	0.52	0.45	.00525
1982	.095	0.44	0.38	.00570
1983	.113	0.37	0.32	.00565
1984	.104	0.30	0.26	.00416
1985	.083	0.22	0.19	.00249
1986	.109	0.15	0.13	.00218
1987	.120	0.08	0.07	.00120
1988	.028	0.00	0.00	.00000
	.993**		Total Benefit	.056 gm/mi

---

* This table is for illustration purposes only and should not be used to determine program benefits.

**VMT fractions do not sum to 1.000 because model years older than 19 years account for the remaining VMT. No excess or benefit is assumes for these model years for calculational simplicity.

As discussed earlier these results have not been adjusted for non-standard conditions. Table 25 assumes that there is no I/M program in the area of interest, while Table 26 assumes the existence of an I/M program. For comparison, MOBILE2 predicts that without I/M on January 1, 1988 the total composite emissions from these vehicles to be:

	MOBILE2	
	HC	CO
° Passenger Cars	2.42 gm/mi	27.47 gm/mi
° Light-Duty Trucks:		
(6000 lbs)	2.59 gm/mi	24.80 gm/mi
(6000-8500 lbs)*	1.57 gm/mi	14.11 gm/mi

---

*These heavier trucks emit more HC and CO emissions than passenger cars or the lighter trucks of the same model year, however, MOBILE2 assumes that the majority of the VMT accumulated by these trucks is accumulated by the new (and cleaner) model years so that this composite number shows a lower contribution than would occur if the distribution of VMT were similar to the passenger cars.

These MOBILE2 emission levels, however, assume only an 8% rate of misfueling and contain much smaller rates of tampering than observed in the tampering surveys.

Section 5.0 will discuss how anti-tampering and anti-misfueling programs can reduce the excess emissions and will estimate the benefits of these programs.

The method described in subsection 4.1 aggregates the effects of all forms of tampering for one model year and then combines model years. For Tables 25 and 26, the method was modified to provide the reader not only with the all-forms, all-model years composite excess emission results, but with additional detail on the contributions of different types of tampering to the total.

The excess emissions from each of the 11 unique combinations of tampering and misfueling, plus the excess from PCV and evaporative tampering, were aggregated separately across model years before being combined together with each other. Tables 25 and 26 do not show 13 separate categories of tampering, however, in the interest of comprehension. All of the excess emissions from the six tampering combinations which involve catalyst removal alone or in conjunction with other forms have been added together and appear with the heading of "catalyst removal" in Tables 25 and 26. The remaining four categories involving misfueling are shown together under the "misfueling" heading. The category of air pump tampering only appears under the "air pump tampering" heading.

Table 25

Per Vehicle Excess Emissions Due to Tampering and Misfueling in Non-I/M Areas (January 1, 1988)

Emission Control Component	Composite Per Vehicle Increase in Emissions (mg/mi)					
	Passenger Car		Light-Duty Truck			
			(0-6000 lbs)		(6000-8500 lbs)	
	HC	CO	HC	CO	HC	CO
Air Pump*	30.20	765.89	88.19	1998.97	56.26	1280.56
Catalyst	133.70	1297.91	627.29	5846.52	562.84	5246.07
Misfueling**	151.37	1184.71	364.68	3044.70	325.74	2719.70
PCV System	38.06	0.00	157.84	0.00	229.49	0.00
Evaporative Canister	18.27	0.00	150.89	0.00	96.29	0.00
Totals(mg/mi)	371.59	3248.51	1388.88	10890.21	1270.62	9246.33
Totals(gm/mi)	0.37	3.25	1.39	10.89	1.27	9.25
Tons***	301.80	2638.40	237.00	1858.29	152.95	1113.01

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*Because some of the vehicles with disabled air pumps also had catalysts removed or had been misfueled, the excess emissions due to the overlap has been removed from the air pump category to avoid double counting.

**Because of the overlap between catalyst removal and misfueling, the excess emissions due to the overlap have been removed from the misfueling category to avoid double counting.

***An estimate of annualized tons calculated assuming a fleet of 100,000 vehicles of all types and using MOBILE3 estimates of passenger car and light-duty truck vehicle miles traveled (LDV: 0.614, LDT1: 0.129, LDT2: 0.901). Each vehicle is assumed to have traveled 12,000 miles in the last year.

Table 26

Per Vehicle Excess Emissions Due to Tampering and Misfueling in I/M Areas (January 1, 1988)

Emission Control Component	Composite Per Vehicle Increase in Emissions (mg/mi)					
	Passenger Car		Light-Duty Truck (0-6000 lbs)		Light-Duty Truck (6000-8500 lbs)	
	HC	CO	HC	CO	HC	CO
Air Pump*	13.50	342.74	30.49	688.09	19.21	434.16
Catalyst	46.19	451.26	166.72	1553.10	149.33	1391.17
Misfueling**	92.95	717.55	242.26	2013.11	219.57	1824.29
PCV System	38.06	0.00	157.84	0.00	229.49	0.00
Evaporative Canister	18.27	0.00	150.89	0.00	96.29	0.00
Totals(mg/mi)	208.97	1511.54	748.21	4254.30	713.88	3649.61
Totals(gm/mi)	0.21	1.51	0.75	4.25	0.71	3.65
Tons***	169.72	1227.65	127.67	725.95	85.93	439.31

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*Because some of the vehicles with disabled air pumps also had catalysts removed or had been misfueled, the excess emissions due to the overlap has been removed from the air pump category to avoid double counting.

**Because of the overlap between catalyst removal and misfueling, the excess emissions due to the overlap have been removed from the misfueling category to avoid double counting.

***An estimate of annualized tons calculated assuming a fleet of 100,000 vehicles of all types and using MOBILE3 estimates of passenger car and light-duty truck vehicle miles traveled (LDV: 0.614, LDT1: 0.129, LDT2: 0.091). Each vehicle is assumed to have traveled 12,000 miles in the last year.

5.0 BENEFITS OF ANTI-TAMPERING AND ANTI-MISFUELING PROGRAMS

This section estimates the benefits of anti-tampering and anti-misfueling programs using the data and method described in previous sections. As discussed in the previous sections, the benefits of anti-tampering and anti-misfueling programs will depend on three major factors.

These are:

- The rate of tampering and misfueling in the area.
- The amount of excess emissions caused by tampering and misfueling.
- The effectiveness of the program in eliminating tampering and misfueling.

The rate of tampering and misfueling was addressed in Section 2.0. The amount of excess emissions caused by tampering was discussed in Sections 3.0 and 4.0. This section will discuss the effectiveness of specific anti-tampering and anti-misfueling programs and estimate their benefits in both I/M and non-I/M areas.

There are several factors which influence the effectiveness of anti-tampering and anti-misfueling programs:

- The perceived incentives for tampering and misfueling.
- The ability of the program to detect tampering and misfueling.
- The size of the penalty for tampering and misfueling.
- The extent of enforcement action to assure that the program operates as designed.
- The number of vehicle owners who continue to tamper or misfuel after the program begins.
- The rate of inadvertent disablements.

Each of the following sections will address these issues and decide on an appropriate level of effectiveness for each type of disablement and each program design in both I/M and non-I/M areas.

In order to claim the full benefits estimated in the tables in this section the program must require the following elements to assure operation as designed. Programs lacking some of these elements are feasible but would require individual evaluation.

- Inspector training.
- A method to assure vehicle owner compliance with the program requirements.
- A method to determine which vehicles require which emission control components.
- Data collection to monitor the program and identify bad actors among inspectors, inspection stations, and repair facilities.
- Periodic audits of inspection stations in decentralized programs to verify inspector proficiency and compliance with other program requirements.
- Enforcement actions such as using an "unmarked" test car in decentralized programs to assure inspector compliance with program rules.
- A fraud-resistant referee system for decentralized programs to resolve disputes.
- A public awareness program.

The above design requirements are intended to prevent deliberate cheating. Centralized programs, by their design, should be able to prevent cheating more easily than decentralized programs. The credits calculated in this report assume that there will be no significant amount of cheating in the inspections. EPA will evaluate anti-tampering programs for their ability to prevent cheating before agreeing to allow credits for the program. If EPA review of the program design suggests that significant but unquantifiable cheating could still occur, reduced or no credits would be given.

Public acceptance of a vehicle inspection program which requires catalyst replacement where misfueling is indicated will be improved if there is a visible program to also require compliance with fuel regulations on the part of retail gasoline outlets. The Plumbtesmo test may fail a vehicle whose only use of leaded fuel was inadvertent due to contamination or mislabeling at the pump. EPA does not have enough information to predict the conditions under which this might occur. It is important that these occurrences be minimized for equity reasons. Therefore, EPA advises that if a State or local area intends to use the Plumbtesmo test to detect misfueling, there should also be a program of unscheduled periodic inspections of retail gasoline outlets. This program should inspect the diameter of fuel pump nozzles, determine that the pumps are properly labeled, and analyze the lead content of the fuel being sold.

Benefits from anti-tampering and anti-misfueling programs are obtained by addressing two problems: (1) existing tampering and misfueling and (2) the tampering and misfueling which has not yet occurred. Existing tampering and misfueling can only be addressed by identifying tampered and misfueled vehicles and requiring their repair. Tampering and misfueling that have not yet occurred can be detected when they do occur or can be prevented from occurring by the assurance of detection and penalty in the program. Tampering and misfueling which have already occurred are calculated as the rate of occurrence at the start date of the tampering inspection program (assumed to be January 1, 1984 for the benefits presented here). The tampering and misfueling which will occur between the program start date and the evaluation year without the intervention of the inspection program is the difference in the rates calculated for the start date of the program and the evaluation date, assuming no program.

5.1 I/M Programs

I/M programs offer a good opportunity to address the tampering issue. Although the available data show that I/M programs affect the incidence of tampering and misfueling to some extent without any special activity, substantial amounts of tampering can continue. Fortunately, the fact that large segments of the fleet are periodically inspected provides a low cost, convenient opportunity to specifically check for tampering and misfueling. Some I/M programs have seen the advantages in expanding the inspection and already include a check for tampering.

Section 2.0 discussed the effect of I/M on tampering rates. The I/M rates discussed in that Section are the rates used for all calculations in this Section, except that overlap among tampering types is accounted for as described in Section 4.0. The individual vehicle benefits and costs of repairs of tampering and misfueling are those discussed in Section 3.0. The methodology explained in Section 4.0 was used to calculate excess emissions due to tampering and misfueling. Only annual and biennial programs are considered in this section.

5.1.1 Program Effectiveness

For periodic inspection programs, such as I/M programs, it is assumed that the program will require repair or replacement of the disabled emission control components once they are discovered, followed by reinspection of the vehicle and/or the repair receipts to verify compliance.

The assumptions used to calculate benefits for inspection of individual components and combinations of components are explained and justified below. Section 5.1.2 then presents the results of the calculation of benefits. The details of the calculation are not presented. For all components, benefits are shown separately for 1984 and later vehicles, for 1980 to 1983 vehicles, and for older vehicles, for the convenience of jurisdictions which plan to inspect only 1980 and later or 1984 and later vehicles. Jurisdictions interested in other model year cutoffs may interpolate for a rough approximation and may consult with EPA for an exact calculation.

The only site in the 1982 EPA tampering survey which has an anti-tampering inspection is the Portland, Oregon site. Portland has also had a biennial I/M program since 1975. The fact that Portland has an anti-tampering program is presumably most of the reason why Portland has a lower tampering rate than any of the other I/M sites in the 1982 survey. However, other factors, such as local behavior, the stringency and age of the I/M program, and the age of the anti-tampering program itself probably all contribute to the effectiveness observed in Portland. Also, the survey in Portland was conducted at the I/M inspection site. Vehicle owners presenting their vehicles for inspection knew beforehand that their vehicle would be inspected for tampering and that they would be required to repair any tampering before they could register their vehicle. It is possible, therefore, that a few vehicle owners repaired their vehicles' tampering just before presenting their vehicles for inspection. This would cause the survey to underestimate the actual rate of tampering and misfueling in Portland if some retampering occurs between inspections. In addition, some of the vehicles surveyed probably were at the I/M station for reinspection following repair of tampering discovered in a previous inspection. Comparison to Portland is, therefore, used only as a guide to estimate the effectiveness of anti-tampering programs in other areas. All comparisons to Portland made in the following subsections compare the mixed group of cars and trucks in Portland to the mixed group of cars and trucks in other specified areas.

5.1.1.1 Positive Crankcase Ventilation (PCV) and Evaporative System Inspection

The inspection for the PCV system is quite simple. The inspector need only assure that the PCV valve and connecting hose to the carburetor are both present and connected. The evaporative control system is more complicated. The canister may be located somewhere other than in the engine compartment, misleading an inspector into thinking it has been removed or encouraging the inspector not to check hose connections at the canister. Often there are spaces for extra connections on the canister which are unused even when it is properly connected. A false failure can be avoided by checking the hose routing diagram attached underneath the hood. It is advisable for programs which check the evaporative canister to also require an OEM gas cap to be present. Although the rate of missing gas caps is small, the evaporative control system does not work properly without it. Generic gas caps are often used to replace lost OEM caps, but they may fail to make the tight seal required for effective control of evaporative emissions. Similiar problems may exist with replacement locking type gas caps which are popular in some areas.

In Portland, the rate of disabled PCV systems is 56% less than in the other nine sites in the survey. The rate of evaporative canister tampering is 57% less. This difference is assumed to be entirely due to the tampering check performed in Portland as part of the biennial I/M program. An annual inspection is expected to reduce the number of disablements even more, so an annual PCV check is assumed to be 70% effective and an annual evaporative canister check is assumed to be 70% effective.

The rather low effectiveness values (56% for PCV and 57% for evaporative) observed in Portland are somewhat surprising but can be explained. In the case of the evaporative canister and the PCV system, it can be speculated that many disablements are inadvertent, since there is virtually no incentive for vehicle owners to deliberately disconnect these devices. Moreover, the penalty, reconnection or replacement, is so inexpensive that there is little incentive to repair the systems between inspections even if the owner is aware of the disablements. Consequently, deterrence of these two forms of tampering is probably low. The Portland inspectors also may not be 100% accurate in the inspections for PCV and evaporative systems.

Benefits from a PCV or evaporative canister inspection are reductions in non-exhaust emissions and, therefore, can be added to any of the other inspections which offset exhaust emissions. The benefits from these inspections are unaffected by the presence or absence of the other inspections discussed below.

5.1.1.2 Catalyst-Only Inspection

Inadvertent removal of catalysts does not occur. Therefore, if the public is well informed that failure of the catalyst check will require catalyst replacement, one can expect that there will be few new instances of catalyst removal. Such public awareness should be nearly automatic in an annual program. The exception, if any, will be a small group of owners convinced beyond persuasion that their catalysts should be removed. Such owners may reinstall the catalyst as necessary in order to pass the inspection, or may remove the active material from the catalyst container making visual detection of the disabled catalyst nearly impossible.

In addition to some catalysts being successfully removed or disabled in a way that escapes detection, inadvertent inspector errors may result in failure to replace all catalysts missing at the start of the program. Inspector errors can be minimized by proper training and access to good reference material. Materials are available which list the emission control equipment required on vehicles (Colorado State University, 1968-1982 Automotive Emissions Systems Applications Guide [4]).

It is true that in the 1982 tampering survey, no catalyst removals were observed in over 300 inspections at the Portland site. Since the Portland program has been in operation since the advent of catalyst equipped cars, this indicates that the catalyst inspection can effectively prevent vehicle owners from removing catalysts, except perhaps for a few owners who reinstall the catalyst each time to pass inspection or remove the active material. This deterrence can be achieved with a program which provides a reasonably high probability of detection. The Portland observation is not inconsistent with an assumption that inspections will not be quite 100% accurate.

For the reasons discussed above, an inspection for removal of the catalyst will be assumed to be 95% effective in detecting and forcing replacement of catalysts. The 95% value allows for some inspection errors and some concealed tampering and retampering by owners. A biennial inspection program is assumed to be as effective as an annual inspection.

The effectiveness of 95% applies to the group of vehicles whose only form of tampering is catalyst removal, and it applies both to removals which had occurred before program start-up and to those which would otherwise have occurred between start-up and the evaluation date. Vehicles which have both their catalyst removed and one or more other forms of tampering require special discussion, which follows.

There are five groups of multiple tampered vehicles of interest here: catalyst removed/misfueled(inlet); catalyst removed/misfueled(other): catalyst removed/misfueled (inlet)/air pump disabled: catalyst removed/misfueled (other)/air pump disabled, and catalyst removed/air pump disabled. EPA assumes that 5% of the vehicles in each of these groups will remain there despite an inspection for catalyst presence, due to errors and concealed catalyst tampering or retampering. Of the catalyst removed/misfueled (inlet) and the catalyst removed/misfueled(other) groups, the other 95% are assumed to enter the corresponding misfueled-only group. In other words, owners of these vehicles are forced to replace their catalysts (or are deterred from removing them after inspections begin), but they continue to misfuel thereby poisoning the new catalysts. A poisoned catalyst is only slightly more effective than no catalyst, according to Section 3.0.

Of the catalyst removed/misfueled(inlet)/air pump disabled and the catalyst removed/misfueled(other)/air pump disabled groups, 95% are assumed to enter the corresponding misfueled/air pump disabled group. Of the catalyst removed/air pump disabled group, 95% are assumed to enter the air pump disabled-only group. Except for these new entrants, the rates for other forms of tampering are unaffected.

The following table presents these assumptions in concise form. The format of this table is used for later inspection types also.

Overlap Category	Effect of Catalyst Check
1) Air Pump/Catalyst	95% become air pump only. 5% remain air pump/catalyst.
2) Air Pump/Misfueling (Inlet)	100% remain air pump/misfueling (Inlet).
3) Air Pump/Misfueling (Other)	100% remain air pump/misfueling (Other).
4) Air Pump/Catalyst/ Misfueling (Inlet)	95% become air pump/misfueling (Inlet). 5% remain air pump/catalyst/ misfueling (Inlet).

5) Air Pump/Catalyst/ Misfueling/(Other)	95% become air pump/misfueling (Other). 5% remain air pump/catalyst/ misfueling (Other).
6) Catalyst/Misfueling (Inlet)	95% become misfueling (inlet) only. 5% remain catalyst/misfueling (inlet).
7) Catalyst/Misfueling (Other)	95% become misfueling (other) only. 5% remain catalyst/misfueling (other).
8) Air Pump Only	100% remain air pump only.
9) Catalyst Only	95% become OK. 5% remain catalyst only.
10) Misfueling (Inlet) Only	100% remain misfueling (inlet) only.
11) Misfueling (Other) Only	100% remain misfueling (other) only.

Some owners who have removed their catalysts have probably done so thinking it would harm their vehicles to misfuel while the catalyst was still present. It is assumed above, however, that essentially all vehicle owners, who remove their catalysts and also misfuel, will misfuel even if prevented from removing the catalyst by the program. This assumption is supported by the fact that in the latest tampering survey, 62% of the habitually misfueled vehicles had not removed the catalyst, indicating that most misfuelers believe it is safe to misfuel even if the catalyst is left on the vehicle. Given the perceived incentives for misfueling, owners who are forced to replace catalysts will probably come to believe the same, or will find a way to defeat the catalyst check entirely.

5.1.1.3 Air Pump-Only Inspections

With air pumps, removal or failure of the drive belt is the most likely disablement. Air pump belts may eventually break if they are not periodically replaced. This may account for some portion of observed disablements. Since this disablement is relatively easy to identify and replacement is inexpensive, some deliberate tampering with the air pump may occur even with a vigorous anti-tampering program. Some vehicle owners may be willing to risk detection and the subsequent penalty, replacement of the belt, in order to achieve perceived benefits in fuel economy and performance. Some vehicle owners may even replace and remove their air pump belt before and after their periodic inspection to avoid detection by the program. This would be expected only on the part of die-hard tamperers, however, since such a repair may take a considerable amount of time. To address this problem, the public awareness effort should attempt to eliminate the misperceptions associated with tampering.

In Portland the rate of air pump disablement is about 74% less than in the other I/M sites. However, since the survey was performed at an I/M station where a tampering check is performed, some vehicle owners may have reconnected the air pump for the inspection with the intention of disabling it immediately after meeting the legal requirements. It may be speculated that the number of vehicle owners who do this is only a small portion of the fleet. However, we will assume that an annual inspection program will have an 80% effectiveness, and a biennial program will have a 70% effectiveness. This applies to both existing and subsequent tampering. The calculation of benefits for most programs will not be very sensitive to the choice of effectiveness values for air pump inspections, as the air pump-only category is small and has a relatively small emissions excess.

The above effectiveness values apply only to the group of vehicles which have air pump disablement as the only form of tampering. In other words, 70% or 80% of these vehicles are restored to a tamper-free state with reduced emissions and the remainder stay as they were (or as they would have otherwise become). Similarly, 70% or 80% of the vehicles with disabled air pumps which were also misfueled revert to a misfueled-only status, but under the assumptions given in Section 4.0 their emissions are not reduced. The same holds for cars with disabled air pumps and missing catalysts, with or without misfueling. The table of effects is omitted here, since it is very simple and not required for understanding of the effectiveness assumptions.

5.1.1.4 Fuel Inlet Restrictor-Only and Inlet/Air Pump Inspections

Two types of inspection requirements for the fuel inlet restrictor are discussed here and defined as "fuel inlet restrictor-only" inspections. One would require repair only of the restrictor when it was found to be tampered. The other would require replacement of the catalyst and repair of the restrictor but would not inspect for catalyst presence. This document does not contain benefits for either of these approaches, and EPA does not recommend either approach for new anti-tampering programs.

The first approach, repair of the restrictor only, would have no benefit for the vehicles, since poisoned catalysts would remain and cannot be expected to recover their function. It would also have very limited deterrence for subsequent misfueling, since the penalty of a restrictor repair is relatively low, since no catalyst replacements would take place, and since other means to misfuel could be used.

The second approach, repair of both catalyst and restrictor, would in principle have benefits. However, the inequity of not also requiring new catalysts on vehicles with missing catalysts (regardless of inlet status) would in EPA's opinion be contrary to the objectives of an anti-tampering program.

The above discussion also applies to an inlet inspection combined with an air pump inspection, so no benefits for it are given in this document.

Inlet restrictor inspections are most useful in combination with catalyst presence inspections, which are discussed in subsection 5.1.1.7 below.

5.1.1.5 Plumbtesmo-Only Inspections

Just as with inlet-only inspection, it is in concept possible to perform only a Plumbtesmo inspection, with the penalty being a mandatory catalyst replacement. However, it is inequitable to force catalyst replacement for a vehicle which fails Plumbtesmo without also forcing it for a vehicle with a tampered fuel inlet. In addition, equity requires that vehicles with missing catalysts also be repaired in any program that requires misfueled vehicles to have the catatlyst replaced.

Consequently, this report does not contain benefits for programs that perform Plumbtesmo tests without also doing inlet checks, or for programs that do inspect for both of these but not for catalyst presence as well. The same holds for Plumbtesmo/air pump, Plumbtesmo/inlet/air pump, Plumbtesmo/catalyst, and Plumbtesmo/air pump/catalyst inspections.

5.1.1.6 Catalyst and Air Pump Inspections

An inspection for catalyst presence and air pump is a feasible approach. The benefits are based on assumptions consistent with those stated above in Sections 5.1.1.2 and 5.1.1.3 for catalysts and air pump separately. Some minor additional assumptions for overlap categories affected by both inspections are necessary, however. Specifically, the catalyst/air pump inspection has the following effects on the different overlap categories:

Overlap Category	Effect of Catalyst/Air Pump Check
1) Air Pump/Catalyst	80% (70% if biennial) become OK. 15% (25% if biennial) become air pump only. 5% remain air pump/catalyst.
2,3) Air Pump/Misfueling	80% (70% if biennial) become misfueling only. 20% (30% if biennial) remain air pump/misfueling.
4,5) Air Pump/Catalyst/ Misfueling	80% (70% if biennial) become misfueling only. 15% (25% if biennial) become air pump/misfueling. 5% remain air pump/catalyst/ misfueling.
6,7) Catalyst/Misfueling	95% become misfueling only. 5% remain catalyst/misfueling.
8) Air Pump Only	80% (70% if biennial) become OK. 20% (30% if biennial) remain air pump only.
9) Catalyst Only	95% become OK. 5% remain catalyst only.
10,11) Misfueling Only	100% remain misfueling only.

The above description applies for both tampering which is present in the fleet when the catalyst/air pump check is initiated and tampering which would otherwise have occurred subsequently.

5.1.1.7 Catalyst and Fuel Inlet Restrictor Inspections

Inspection of the fuel inlet restrictor is straightforward, and there is no reason to expect errors if inspectors are diligent. However, the real issue is the effectiveness of the inlet inspection in causing poisoned catalysts to be replaced and not re-misfueled, and in deterring misfueling which would otherwise occur after the start of the catalyst/inlet check. Clearly, an inlet check will not reduce misfueling that occurs by means other than inlet tampering.

EPA believes that an inlet check alone will be far from completely effective for misfueling accomplished by inlet tampering, for reasons explained below. However the Agency is willing to evaluate innovative inspection programs which attempt to enhance the effectiveness of simple inlet checks. EPA Regional Offices should be contacted to discuss alternative approaches.

It is assumed that any fuel inlet restrictor which allows entry of a legal size leaded fuel nozzle is an indication of habitual misfueling and, therefore, that the catalyst has been rendered inoperative. Therefore, if the fuel inlet restrictor has been enlarged, the vehicle owner must be required to replace the catalyst. In addition, the vehicle owner will have to repair or replace the restrictor so that a leaded fuel nozzle will not fit.

Misfuelers are divided into four categories for anaylsis: 1) existing misfuelers with tampered inlets only, 2) existing misfuelers with both tampered inlet and missing catalyst, 3) existing misfuelers without tampered inlet, 4) future misfuelers.

The category one misfuelers are a problem group. It is unclear how many of the misfuelers will pre-fix their inlets or will continue to misfuel even after detection and catalyst replacement. Because of this uncertainty an assumption is made that many will continue to misfuel or will pre-fix.

An owner may defeat the inspection by simply repairing the inlet prior to the first inspection, if he or she is aware of the start of the catalyst/inlet check and of the consequences of failure. An owner who has submitted his or her vehicle for inspection, and who has failed the inlet check and then learned of catalyst replacement consequences can still defeat the program by repairing the inlet and seeking another inspection as though the vehicle had not already been inspected, unless additional safeguards are imposed. This can be prevented, for example, by punching the vehicle registration card at the first inspection, or a similar measure, but this would not solve the problem of misfuelers who have advance warning of the consequences of inlet failure. Even if an owner replaces the catalyst after failing the inlet check, there is the possibility of re-misfueling using means other than inlet tampering.

Category 2 misfuelers will be much easier to catch and deter. They will be caught because if they pre-fix their inlet they will still fail the catalyst check. Also, it is unlikely that they will continue to fuel switch after detection because besides the large cost of catalyst and inlet replacement which they will incur, most if not all of this group believe that they must remove their catalyst in order to fuel switch.

It is assumed that category three misfuelers are not deterred at all.

With respect to misfueling which would have occurred subsequent to the start of the catalyst/inlet check, (category 4 misfueling), EPA believes the effectiveness of the inlet check will be limited only by the opportunity for potential misfuelers to be able to misfuel by other means and by whether they perceive the benefits of misfueling as outweighing the potential of being caught by the inspection program. Public awareness programs should be targeted directly at this group. This fact plus the existence of an inspection check which will prevent them from tampering with their inlet or removing their catalyst, should result in significant levels of deterrence of future misfueling.

There is an assumption that the mere existence of an idle test will increase the effectiveness of an inlet check, because vehicle owners will be concerned that misfueling will cause failure of the idle test.

In light of the above considerations, EPA has made the following assumptions regarding the effect of a catalyst/inlet check in areas with an I/M program.

Overlap Category	Effect of Catalyst/Inlet Check
1) Air Pump/Catalyst	95% become air pump only. 5% remain air pump/catalyst.
2) Air Pump/Misfueling (Inlet)	33% of vehicles initially in this category become air pump only. 67% of vehicles initially in this category remain air pump/ misfueling. 70% of vehicles which would otherwise enter this category subsequent to the start of the program become air pump only instead.

	30%	of vehicles which would otherwise enter this category subsequent to the start of the program remain air pump/misfueling.
3) Air Pump/Misfueling (Other)	100%	remain air pump/misfueling.
4) Air Pump/Catalyst/Misfueling (Inlet)	59%	of "initial" vehicles become air pump only.
	36%	of "initial" vehicles become air pump/misfueling.
	5%	of "initial" vehicles remain air pump/catalyst/misfueling.
	70%	of "subsequent" vehicles become air pump only.
	25%	of "subsequent" vehicles become air pump/misfueling only.
	5%	of "subsequent" vehicles remain air pump/catalyst/misfueling.
5) Air Pump/Catalyst/Misfueling (Other)	95%	become air pump/misfueling.
	5%	remain air pump/catalyst/misfueling.
6) Catalyst/Misfueling (Inlet)	36%	of "initial" vehicles become misfueling only.
	59%	of "initial" vehicles become OK.
	5%	of "initial" vehicles remain catalyst/misfueling.
	25%	of "subsequent" vehicles become misfueling only.
	70%	of "subsequent" vehicles become OK.
	5%	of "subsequent" vehicles remain catalyst/misfueling.
7) Catalyst/Misfueling (Other)	95%	become misfueling only.
	5%	remain catalyst/misfueling.
8) Air Pump Only	100%	remain air pump only.
9) Catalyst Only	95%	become OK.
	5%	remain catalyst only.
10) Misfueling (Inlet) Only	33%	of "initial" vehicles become OK.
	67%	of "initial" vehicles remain misfueling only.
	70%	of "subsequent" vehicles become OK.

	30% of "subsequent" vehicles remain misfueling only.
11) Misfueling (Other) Only	100% remain misfueling only.

5.1.1.8 Catalyst, Fuel Inlet Restrictor, and Air Pump Inspections

Adding an air pump inspection to a catalyst/inlet check has the effect of correcting most air pump disablements, without altering the effectiveness for catalyst removal and misfueling. The following overlap categories are affected differently than stated in Section 5.1.1.7 for a catalyst/inlet check. Those not listed are affected the same as described in Section 5.1.1.7.

Overlap Category	Effect of Catalyst/Inlet/Air Pump Check
1) Air Pump/Catalyst	80% (70% if biennial) become OK. 15% (25% if biennial) become air pump only. 5% remain air pump/catalyst.
2) Air Pump/Misfueling (Inlet)	33% of "initial" vehicles become OK. 47% (37% if biennial) of "initial" vehicles become misfueling only. 20% (30% if biennial) of "initial" vehicles remain air pump/misfueling. 70% of "subsequent" vehicles become OK. 10% (0% if biennial) of "subsequent" vehicles become misfueling only. 20% (30% if biennial) of "subsequent" vehicles remain air pump/misfueling.
3) Air Pump/Misfueling (Other)	80% (70% if biennial) become misfueling only. 20% (30% of biennial) remain air pump/misfueling.
4) Air Pump/Catalyst/Misfueling (Inlet)	59% of "initial" vehicles become OK. 21% (11% if biennial) of "initial" vehicles become misfueling only. 15% (25% if biennial) of "initial" vehicles become air pump/misfueling only.

	5% of "initial" vehicles remain air pump/catalyst/misfueling. 70% of "subsequent" vehicles become OK. 10% (0% if biennial) of "subsequent" vehicles become misfueling only. 15% (25% if biennial) of "subsequent" vehicles become air pump/misfueling. 5% of "subsequent" vehicles remain air pump/catalyst/misfueling.
5) Air Pump/Catalyst/ Misfueling (Other)	80% (70% if biennial) become misfueling only. 15% (25% if biennial) become air pump/misfueling. 5% remain air pump/catalyst/misfueling.
8) Air Pump Only	80% (70% if biennial) become OK. 20% (30% if biennial) remain air pump only.

5.1.1.9 Catalyst, Fuel Inlet Restrictor, and Plumbtesmo Inspections

As was pointed out in Section 2.0 EPA has been using a lead-sensitive chemically coated paper, whose trade name is Plumbtesmo, to detect tell-tale lead deposits in the tailpipes of vehicles in the latest tampering surveys.[2] This test is a powerful tool in detecting previous use of leaded fuel when there is no leaded fuel in the tank or damage to the fuel inlet restrictor. Its primary fault lies in its inability to determine the extent of catalyst damage due to misfueling. EPA does not know how long lead deposits from misfueling remain in the tailpipe, therefore the possibility cannot now be ruled out that a single tankful of leaded fuel used during an emergency or bought from an unscrupulous gasoline dealer as unleaded may cause a Plumbtesmo test failure months later, even though unleaded fuel has been used at all other fuelings.

If some simple, reliable test to determine the extent of damage to the catalyst by lead deposits could be developed, then such a test could be used to allow vehicle owners whose vehicles fail the Plumbtesmo test to prove that their catalysts were still active and did not need to be replaced. Without such a test, persons who do not deliberately misfuel but accidentally buy leaded gas might be caught by the Plumbtesmo test. Although EPA is currently assessing the feasibility of such a catalyst diagnostic test, no simple test is as yet available. Inequities will be reduced by an aggressive program of sampling fuel from retail gas stations.

Since the required catalyst replacement cost associated with a Plumbtesmo failure would be expensive, some vehicle owner dissatisfaction with the Plumbtesmo test will result unless a back-up catalyst efficiency test is available as a second opinion. Thus EPA recommends the use of a back-up test when requested by a vehicle owner whose vehicle's fuel inlet restrictor has not been defeated and who contends that leaded fuel has not been used.

A less serious, but equally complicating factor is the fact that in EPA tests some vehicles which have obviously been misfueled pass the Plumbtesmo test. As yet no full explanation has been determined for those cases.* As a result, some grossly misfueled vehicles may escape detection by a Plumbtesmo test.

The main attraction of the Plumbtesmo test is its potential effectiveness in deterring misfueling. With a Plumbtesmo inspection, vehicle owners could never be sure that they could avoid detection if they misfuel, even though the EPA experience is that only about one-half of habitually misfueled vehicles will fail the test. Besides this high false negative rate, there is also the possibility that vehicle owners will attempt to circumvent the Plumbtesmo test by cleaning or replacing their tailpipes prior to inspection. However, these acts would make misfueling much less attractive.

A program which would require replacement of the catalyst whenever a vehicle fails the Plumbtesmo test or has a tampered inlet is assumed to prevent 85% of misfueling which would otherwise have occurred. Since the tailpipe would be contaminated with lead, replacement or cleaning of the tailpipe as well as replacement of the catalyst would be required to avoid a Plumbtesmo test failure at the next inspection.

The 85% value pertains only to deterrence of continued or new misfueling, and is based on the psychological effect of the Plumbtesmo test on misfueling bahavior. For vehicles which were misfueled before the inspection program started, the actual effectiveness will be less. Even if previous misfuelers stop misfueling in an attempt to avoid failure of the Plumbtesmo test, there will be emission reductions only in the cases in which the previous misfueling is detected and the catalyst is replaced. In the EPA survey, about 80% of habitually misfueled vehicles failed the combination inlet and Plumbtesmo check. In a real program, owners of misfueled vehicles which fail only the inlet check (one-fourth of the 80%) might successfully defeat the inlet check and avoid catalyst replacement, as described in Section 5.1.1.7 above. However, some vehicles will fail Plumbtesmo which in the EPA survey would not have counted as habitually misfueled but which likely have suffered some catalyst damage. EPA assumes that these two influences approximately balance each other, and has assumed a 75% effectiveness for previous misfueling, regardless of the means used to accomplish it. For subsequent misfueling, the 85% value is used directly.

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*One possible explanation is that the unstable lead-detecting compounds in the test paper became inadvertently deactivated, or a defective lot was used during testing. An inspection program forewarned of these problems could easily avoid using inactive test paper.

As noted earlier, because a Plumbtesmo test may fail a vehicle whose only use of leaded fuel was inadvertent due to contamination or mislabeling at the pump, it is important that these occurrences be minimized. This can be done establishing the program of fuel pump inspections described at the beginning of Section 5.0.

In detail, the effect of a catalyst/inlet/Plumbtesmo inspection is assumed to be as follows:

Overlap Category	Effect of Catalyst/ Inlet/Plumbtesmo Check
1) Air Pump/Catalyst	95% become air pump only. 5% remain air pump/catalyst.
2,3) Air Pump/Misfueling	75% of "initial" vehicles become air pump only. 25% of "initial" vehicles remain air pump/misfueling. 85% of "subsequent" vehicles become air pump only. 15% of "subsequent" vehicles remain air pump/misfueling.
4,5) Air Pump/Catalyst/ Misfueling	75% of "initial"vehicles become air pump only. 20% of "initial" vehicles become air pump/misfueling. 5% of "initial" vehicles remain air pump/catalyst/misfueling.

	85% of "subsequent" vehicles become air pump only. 10% of "subsequent" vehicles become air pump/misfueling. 5% of "subsequent" vehicles remain air pump/catalyst/misfueling.
6,7) Catalyst/Misfueling	75% of "initial" vehicles become OK. 20% of "initial" vehicles become misfueling only. 5% of "initial" vehicles remain catalyst/misfueling. 85% of "subsequent" vehicles become OK. 10% of "subsequent" vehicles become misfueling only. 5% of "subsequent" vehicles remain catalyst/misfueling.
8) Air pump Only	100% remain air pump only.
9) Catalyst Only	95% become OK. 5% remain catalyst only.
10,11) Misfueling Only	75% of "initial" vehicles become OK. 25% of "initial" vehicles remain misfueling only. 85% of "subsequent" vehicles become OK. 15% of "subsequent" vehicles remain misfueled only.

5.1.1.10 Catalyst, Fuel Inlet Restrictor, Plumbtesmo, and Air Pump Inspections

Adding an air pump inspection to the previous combination of catalyst/inlet/Plumbtesmo results in correction or deterrence of most air pump disablements. Correction of misfueling and catalyst removal is not changed. In detail, the effect of a catalyst/inlet/Plumbtesmo/air pump inspection is assumed to be as follows:

Overlap Catagory	Effect of Catalyst/Inlet/ Plumbtesmo/Air Pump Check
1) Air Pump/Catalyst	80% (70% if biennial) become OK. 15% (25% if biennial) become air pump only. 5% remain air pump/catalyst.
2,3) Air Pump/Misfueling	75% (70% if biennial) of "initial" vehicles become OK.

	5% (0% if biennial) of "initial" vehicles become misfueling only. 0% (5% if biennial) of "initial" vehicles become air pump only. 20% (25% if biennial) of "initial" vehicles remain air pump/misfueling. 80% (70% if biennial) of "subsequent" vehicles become OK. 5% (15% if biennial) of "subsequent" vehicles become air pump only. 15% of "subsequent" vehicles remain air pump/misfueling.
4,5) Air Pump/Catalyst Misfueling	75% (70% if biennial) of "initial" vehicles become OK. 5% (0% if biennial) of "initial" vehicles become misfueling only. 0% (5% if biennial) of "initial" vehicles become air pump only. 15% (20% if biennial) of "initial" vehicles become air pump/misfueling only. 5% of "initial" vehicles remain air pump/catalyst/misfueling. 80% (70% if biennial) of "subsequent" vehicles become OK. 5% (15% if biennial) of "subsequent" vehicles become air pump only. 10% (10% if biennial) of "subsequent" vehicles become air pump/misfueling only. 5% of "subsequent" vehicles remain air pump/catalyst/misfueling.
6,7) Catalyst/Misfueling	75% of "initial" vehicles become OK. 20% of "initial" vehicles become misfueling only. 5% of "initial" vehicles remain catalyst/misfueling. 85% of "subsequent" vehicles become OK. 10% of "subsequent" vehicles become misfueling only. 5% of "subsequent" vehicles remain remain catalyst/misfueling.
8) Air Pump Only	80% (70% if biennial) become OK. 20% (30% if biennial) remain air pump only.

9) Catalyst Only	95% become OK. 5% remain catalyst only.
10,11) Misfueling Only	75% of "initial" vehicles become OK. 25% of "initial" vehicles remain misfueling only. 85% of "subsequent" vehicles become OK. 15% of "subsequent" vehicles remain misfueled only.

5.1.2 Results: Benefits for I/M Programs

Table 27 presents the benefits of inclusion of a tampering inspection with an annual I/M program. There are separate results for pre-1980, 1980 through 1983, and 1984 and later vehicles, so that the benefits from programs which exempt pre-1980 or pre-1984 vehicles can be estimated. Table [illegible] presents a biennial version for each of the benefits in Table 27. Tables 27 and 28 were prepared using assumptions given in Section 5.1.1.

5.1.3 Program Costs

This subsection states assumptions necessary to calculate the cost of a tampering inspection program when added to an existing I/M program.

Repairs - The obvious cost of anti-tampering and anti-misfueling programs is the cost to vehicle owners for repairs of disablements, whether they were deliberate or inadvertent. In terms of all cars being inspected, the per vehicle cost for repairs will be relatively small, since usually only some small fraction of vehicles will require repairs. Also, if the program continues to operate beyond December 31, 1987, the cost-effectiveness of the repairs will improve until essentially the only cost incurred by the program will be the cost of inspection. Section 3.0 discusses the repair costs which we have assumed for this analysis.

Using the rate of tampering at the start of the program, the number of vehicles which require repairs at the start of the program can be estimated. By assuming an average repair cost, the initial year repair cost can be estimated.

After the program begins, some tampering will continue to occur and subsequently be detected and repaired. The number of vehicles tampered after the program begins will depend on the effectiveness of the program in deterring tampering and the rate at which new vehicles move into the area. The effectiveness will depend on which emission control components are inspected. For catalyst and fuel inlet restrictor tampering, it is assumed that only those vehicles identified in the first year of the program will require repairs. Vehicles not identified are assumed to continue to avoid detection in subsequent years. Also, no significant amount of new tampering is expected to be discovered in subsequent years since vehicle owners will be aware of the program and its penalties. Air pump, PCV, and evaporative canister disablements occur at moderate rates even in an inspection program which checks for such disablements. In these cases all disablements are assumed to be repaired in the first year, and in each subsequent year repairs will be done on all disablements which reappear.

Inspections - In addition to the cost vehicle owners must pay in repairs, a tampering inspection program will result in increased inspection costs and extra administrative costs related to the tampering inspection. A rough estimate of the additional costs can be made by estimating the increase in personnel time, both inspector and administrative, necessary to include the tampering check.

In decentralized programs, only the additional time an inspector will need to perform the tampering check should be attributed to the anti-tampering program. As with centralized programs, administrative costs can probably be estimated by the need to hire additional personnel.

It is expected that most of the duties required by the addition of a tampering inspection can be integrated into the operation of the I/M program without any substantial increase in program costs. Although this cost will likely vary substantially from program to program depending on many factors, EPA assumes an overall increase in program administrative and inspection costs to be 34 cents in centralized and $1.00 in decentralized inspection programs per inspection, as an example. This added cost would include not only additional costs to perform the inspections but also include additional administrative duties to oversee the additional program elements.

The cost has been estimated by assuming that a single inspector in a centralized program could complete the necessary inspection and additional paperwork for a check of all the components in about one minute. If the inspector is a mechanic costing $20 per hour including fringe benefits and overhead, this works out to be about 34 cents per inspection. In a decentralized program, the inspector will be less specialized and will likely take longer to satisfactorily complete the inspection. We have assumed the decentralized program inspector will take three minutes to complete the inspection, which at $20 per hour, will be $1.00 per inspection. These estimates are for an inspection of all items discussed in this report. An inspection of fewer items would be shorter and, therefore, cheaper.

If a Plumbtesmo inspection is performed, the cost of the test paper may be significant when calculating overall program costs. EPA has purchased Plumbtesmo paper at a price of 43 cents for a piece of paper which is large enough to cut in half for testing two vehicles. A per vehicle cost of 7 cents is possible in inspection programs because large quantities of test paper can be purchased at one time.

5.1.4 Cost-Effectiveness

Because local variations in program design and costs affect the cost-effectiveness calculation, this report does not attempt to calculate cost-effectiveness for all of the numerous possible program types.

5.2 Non-I/M Periodic Inspection Programs

Non-I/M periodic inspection programs offer another opportunity to address the tampering issue. A tampering program can be added to a periodic safety inspection, or an entirely new inspection requirement can be established. Costs will obviously be higher in the latter approach.

Section 2.0 discussed tampering rates in non-I/M areas. The rates discussed in that section are the rates used for all calculations in this section, except that overlap is accounted for among tampering types. The individual vehicle benefits and costs of repairs of tampering and misfueling are those discussed in Section 3.0. The methodology explained in Section 4.0 was used to calculate excess emissions due to tampering and misfueling. Only annual and biennial inspection programs are considered in this section.

5.2.1 Program Effectiveness

For periodic inspection programs as in I/M programs, it is assumed that the program will require repair or replacement of the disabled emission control components once they are discovered, followed by reinspection of the vehicle and/or the repair receipts to verify compliance. In addition, to claim the benefits estimated in this section, the inspection program would have the same requirements as anti-tampering and anti-misfueling programs in I/M programs described at the beginning of Section 5.0. All of the effectiveness assumptions used for I/M programs will be assumed to apply to periodic inspections which are not part of I/M programs with one exception which is explained in more detail in the following paragraph. The reader should refer to Section 5.1.1 for the discussion of inspection effectiveness for all other components and inspection types.

The exception that distinguishes tampering inspection programs in I/M areas and non-I/M areas concerns the effectiveness of fuel inlet restrictor inspections without accompanying Plumbtesmo inspections. As stated in 5.1.1.7, EPA believes that in non-I/M areas owners are more likely to feel that defeating the inlet check is an easy, safe, and reliable way to permanently avoid the requirement for a catalyst replacement. Therefore, EPA assumes a lower effectiveness for inlet inspections in non-I/M areas. The specific assumptions are as follows:

Overlap Category	Effect of Catalyst/Inlet Checks
1) Air Pump/Catalyst	95% become air pump only. 5% remain air pump/catalyst.
2) Air Pump/Misfueling (Inlet)	17% of "initial" vehicles become air pump only. 83% of "initial" vehicles remain air pump/misfueling. 30% of "subsequent" vehicles become air pump only. 70% of "subsequent" vehicles remain air pump/misfueling.
3) Air Pump/Misfueling (Other)	100% remain air pump/misfueling.
4) Air Pump/Catalyst/ Misfueling (Inlet)	33% of "initial" vehicles become air pump only. 62% of "initial" vehicles become air pump/misfueling only. 5% of "initial" vehicles remain air pump/catalyst/misfueling. 30% of "subsequent" vehicles become air pump only. 65% of "subsequent" vehicles become air pump/misfueling only. 5% of "subsequent" vehicles remain air pump/catalyst/misfueling.

5) Air Pump/Catalyst/ Misfueling (Other)	95% become air pump/misfueling only. 5% remain air pump/catalyst/misfueling.
6) Catalyst/Misfueling (Inlet)	33% of "initial" vehicles become OK. 62% of "initial" vehicles become misfueling only. 5% of "initial" vehicles remain catalyst/misfueling. 30% of "subsequent" vehicles become OK. 65% of "subsequent" vehicles become misfueling only. 5% of "subsequent" vehicles remain catalyst/misfueling.
7) Catalyst/Misfueling (Other)	95% become misfueling only. 5% remain catalyst/misfueling.
8) Air Pump Only	100% remain air pump only.
9) Catalyst Only	95% become OK. 5% remain catalyst only.
10) Misfueling Only (Inlet)	17% of "initial" vehicles become OK. 83% of "initial" vehicles remain misfueling only. 30% of "subsequent" vehicles become OK. 70% of "subsequent" vehicles remain misfueling only.
11) Misfueling Only (Other)	100% remain misfueling only.

Overlap Category	Effect of Catalyst/Inlet/Air Pump Checks
1) Air Pump/Catalyst	80% (70% if biennial) become OK. 15% (25% if biennial) become air pump only. 5% remain air pump/catalyst.
2) Air Pump/Misfueling (Inlet)	17% of "initial" vehicles become OK. 63% (53% if biennial) of "initial" vehicles become misfueling only. 20% (30% if biennial) of "initial" vehicles remain air pump/misfueling. 30% of "subsequent" vehicles become OK. 50% (40% if biennial) of "subsequent" vehicles become misfueling only. 20% (30% if biennial) of "subsequent" vehicles remain air pump/misfueling.

3) Air Pump/Misfueling (Other)	80% (70% if biennial) become misfueling only. 20% (30% if biennial) remain air pump/misfueling.
4) Air Pump/Catalyst/Misfueling (Inlet)	33% of "initial" vehicles become OK. 47% (37% if biennial) of "initial" vehicles become misfueling only. 15% (25% if biennial) of "initial" vehicles become air pump/misfueling only. 5% of "initial" vehicles remain air pump/catalyst/misfueling. 30% of "subsequent" vehicles become OK. 50% (40% if biennial) of "subsequent vehicles become misfueling only. 15% (25% if biennial) of "subsequent" vehicles become air pump/misfueling only. 5% of "subsequent vehicles remain air pump/catalyst/misfueling.
5) Air Pump/Catalyst/Misfueling (Other)	80% (70% if biennial) become misfueling only. 15% (25% if biennial) become air pump/misfueling only. 5% remain air pump/catalyst/misfueling
6) Catalyst/Misfueling (Inlet)	33% of "initial" vehicles become OK 62% of "initial" vehicles become misfueling only. 5% of "initial" vehicles remain catalyst/misfueling. 30% of "subsequent" vehicles become OK. 65% of "subsequent" vehicles become misfueling only. 5% of "subsequent" vehicles remain catalyst/misfueling.
7) Catalyst/Misfueling (Other)	95% become misfueling only. 5% remain catalyst/misfueling.
8) Air Pump Only	80% (70% if biennial) become OK. 20% (30% if biennial) remain air pump only.
9) Catalyst Only	95% become OK. 5% remain catalyst only.
10) Misfueling Only (Inlet)	17% of "initial" vehicles become OK 83% of "initial" vehicles remain misfueling only.

	30% of "subsequent" vehicles become OK. 70% of "subsequent" vehicles remain misfueling only.
11) Misfueling Only (Other)	100% remain misfueling only.

As pointed out in Section 2.0, areas without I/M programs tend to have higher tampering and misfueling rates than I/M areas. In this section, all benefits are calculated using tampering and misfueling rates predicted for non-I/M areas.

5.2.2 Results: Benefits for Non-I/M Periodic Inspection Programs

Table 29 presents the benefits of an annual tampering inspection program. There are separate results for pre-1980, 1980 through 1983, and 1984 and later vehicles so that the benefits from programs which exempt pre-1980 or pre-1984 vehicles can be estimated. Table 30 presents a biennial version for each of the benefits in Table 29.

5.2.3 Program Costs

This subsection states assumptions necessary to calculate the cost of a tampering inspection program when added to an existing safety inspection program or when initiated independently.

Repairs - The obvious cost of anti-tampering and anti-misfueling programs is the cost to vehicle owners for repairs of disablements, whether they were deliberate or inadvertent. In terms of all cars being inspected, the per vehicle cost for repairs will be relatively small, since usually only some small fraction of vehicles will require repairs. Also, if the program continues to operate beyond December 31, 1987, the cost-effectiveness of the repairs will improve until essentially the only costs incurred by the program will be the cost of inspection. Section 3.0 discusses the repair costs which we have assumed for this analysis.

Using the rate of tampering at the start of the program, the number of vehicles which require repairs at the start of the program can be estimated. By assuming an average repair cost, the initial year repair cost can be estimated.

After the program begins, some tampering will continue to occur and subsequently be detected and repaired. The number of vehicles tampered after the program begins will depend on the effectiveness of the program in deterring tampering and the rate at which new vehicles enter the program area. The effectiveness will depend on the emission control component. For catalyst and fuel inlet restrictor tampering, it is assumed that only those vehicles identified in the first year of the program will require repairs. Vehicles not identified are assumed to continue to avoid detection in subsequent years. Also, no significant amount of new tampering is expected to be discovered in subsequent years since vehicle owners will be aware of the program and its penalties. Air pump, PCV, and evaporative canister disablements occur at moderate rates even in an inspection program which checks for such disablements. In these cases all disablements are assumed to be repaired in the first year and in each subsequent year repairs will be done on all disablements which reappear.

Tampering Inspections Added to Safety - In addition to the cost vehicle owners must pay in repairs, a safety inspection program which adds a tampering check will incur additional expenses from the added tampering inspections at individual inspection stations and additional administrative costs related to adding the tampering inspection to the I/M requirements. A rough estimate of the additional costs can be made by estimating the increase in personnel time, both inspector and administrative, necessary to include the tampering check.

In centralized inspection programs the tampering inspection might be added to the inspection procedure without any needed increase in personnel. This would be the case if personnel and operating hours did not require expansion; better scheduling of inspections or simply tolerating longer waiting lines could be used to allow tampering inspections with the existing facility and personnel time constraints. It is more likely that additional inspectors, administrative personnel, or possibly inspection stations would be required. In such cases the added salaries of the additional personnel and other costs would be attributed to the tampering inspection.

In decentralized programs, only the additional time an inspector will need to perform the tampering check should be attributed to the anti-tampering program. As with centralized programs, administrative costs can probably be estimated by the need to hire additional personnel.

It is expected that most of the duties required by the addition of a tampering inspection can be integrated into the operation of the safety program without any substantial increase in program costs. Although this cost will likely vary substantially from program to program depending on many factors, EPA assumes an overall increase in program administrative and inspection costs to be 34 cents for centralized and $1.00 for decentralized programs per inspection, as an example. This added cost would include not only additional costs to perform the inspections, but also include additional administrative duties to oversee the additional program elements. Section 5.1.3 discusses how these costs were estimated.

If a Plumbtesmo test is conducted, the cost of the test paper must be considered. A per vehicle cost of 7 cents should be possible in inspection programs where large quantities of test paper can be purhcased at one time.

Tampering Inspections Without Safety - In this case, the tampering check is responsible for the full cost of the inspection program, including the cost of facilities and personnel that in existing safety programs can be attributed to the safety element. Costs in such a program would probably range from $5 to $10.

5.3 Other Anti-Tampering and Anti-Misfueling Programs

The anti-tampering and anti-misfueling programs in this subsection do not involve periodic inspection of vehicles and, therefore, must rely more heavily on the possibility of detection to deter misfueling and tampering. Correction of tampering already present at the start of the program will be less complete than in a periodic inspection program, since only a fraction of the fleet is ever directly affected by the enforcement actions. (Owners of already tampered vehicles will wait until caught before repairing their vehicles since it is assumed that there is no fine in addition to repairs.) As a result, the uncertainty inherent in the benefits from these programs is larger than in programs where every vehicle is inspected periodically.

Although there are numerous ways in which tampering and misfueling might be reduced without periodic inspection, this report will focus only on a few approaches which seem to provide the best probability of large emission benefits and low uncertainty. Other approaches not considered in this report may also provide similar benefits. If an area wishes to investigate programs other than those analyzed in this report, the EPA Regional Office should be contacted for an evaluation of the potential of the specific approach proposed.

To claim all of the benefits estimated in the tables in this section, the anti-tampering and anti-misfueling program must meet all of the requirements outlined at the beginning of

Section 5.0. These include such design features as periodic audits and inspector training.

5.3.1 Change-of-Ownership Inspection Programs

A change-of-ownership anti-tampering inspection program would require an inspection of the vehicle to assure proper connection of the emission control devices every time the vehicle changed ownership or moved into the area for the first time. Title and registration in the new owner's name would be withheld until the vehicle was in compliance.

Although nearly all vehicles change hands at least once in their lives, the time between sales can vary and will often be many years. This time period would allow vehicle owners an opportunity to operate tampered vehicles for long periods of time before any penalty. Some vehicle owners could avoid any penalty by selling the vehicle outside the area covered by the program or simply retaining or junking the car. Also, within-family transfers are often exempt since any requirements could be easily circumvented by simply leaving the title in the original owner's name. States may also be reluctant to intrude into family transactions. These problems will cause the effectiveness of such programs to be less than for periodic inspection programs.

Vehicle owners of cars with the catalyst removed or misfueled will probably not replace the catalyst until forced to in order to complete the sale. Therefore, the number of catalysts that are replaced will depend on the fraction of vehicles which change ownership each year. The same will be true of vehicle owners who have removed or disabled their air pump. Since evaporative and PCV tampering is assumed to be inadvertant and undeterrable, and to recur after repair, no significant benefit for those systems can be expected in a change-of-ownership program. No benefits for PCV or evaporative system inspections have therefore been estimated.

Benefits from a change-of-ownership inspection program assume that ownership will change in a random fashion, that is older cars will change owners with the same probability as newer cars. For this analysis, it is assumed that 15% of the fleet changes owners each year. This is considered a normal rate. Some areas may differ. Over the initial four years of the program (1984 through 1987) about 48% of the fleet will have changed owners. The benefits therefore assume that 48% of tampering which occurred before the program began will be affected by the program. The effectiveness of the inspection for this 48% will be assumed to be the same as for biennial inspections. This assumes that the efficiency of the inspection will not be significantly less in a change-of-ownership program than in a biennial program. The biennial effectiveness values will also be applied to all of the excess emissions due to tampering that would have occurred after the program began. This assumes that few vehicle owners will tamper knowing that the tampering must be fixed before selling the vehicle.

Tables 31 and 32 show the benefits of a change-of-ownership inspection program. Both I/M and non-I/M cases are given. The I/M area case assumes an annual I/M program is in operation during the change-of-ownership program.

5.3.2 Random Audit for Tampering and Misfueling

A random audit inspection program would commit to inspecting some percentage of the areawide fleet each year, randomly chosen from all vehicles in operation. Steps would of course have to be taken by the program to assure that vehicle owners cannot avoid inspection. Each vehicle would be checked for tampering and failed if tampering were discovered. The vehicle owner would then repair or replace the tampered emission control component and resubmit his or her vehicle for inspection.

There are at least two ways to implement an audit program. The more familiar way would be to select vehicles for audit while they are actually operating on a roadway, and perform the audit inspection immediately on the roadside. Vehicles that failed would be issued a "fix it" ticket and be required to be submitted for reinspection (and examination of repair receipts in the case of catalyst replacement) at a designated location within a certain time period. The cost of repair and the inconvenience of having to be reinspected would serve as the deterrent to tampering. To ensure compliance with the reinspection requirement, a fine would be added for late reinspection, registration denial at next renewal date would be a back-up enforcement strategy, and court proceedings would begin for seriously deliquent vehicle owners. The random roadside approach has the advantage of surprise; vehicle owners are given no opportunity to conceal tampering or misfueling before inspection as they would be in a periodic inspection program. The random roadside approach has the disadvantages that alert motorists can often avoid an inspection trap, inspections would be at times that will often be inconvenient to drivers, and poor weather can make it difficult to achieve desired inspection volumes.

The second approach is to use the vehicle registration system to select cars for audits and to enforce the repair/reinspection requirement. In this approach, owners of randomly selected vehicles would receive along with their license renewal form a notice that their vehicles had been slected for a tampering/misfueling audit and that before registration renewal can be completed the vehicle must pass inspection at a designated location. This approach would have a back-up enforcement mechanism to ensure that within a certain period after the notice the vehicle either passes inspection or is disposed of outside the program boundaries. The approach has the advantages that true randomness in selection is possible, owners cannot evade inspection by avoiding roadside traps, and inspections are more at the owner's convenience. A disadvantage is that owners have a better opportunity to defeat the inspection by reinstalling a non-functioning catalyst, getting an OEM filler neck restrictor repair, or replacing or cleaning the tailpipe to pass the Plumbtesmo inspection. In this regard, the audit program could be similar to a periodic inspection program. EPA assumes that the advantage of evasion-proof audits in this approach counteracts its lack of surprise relative to the roadisde approach, so that at equal audit rates the two approaches give equal credit, all else being the same. As noted below, the registration system lends itself to greater publicity efforts which may make it more effective, however.

The effectiveness of a roadside pullover program will depend on the number of vehicles actually inspected and the risk perceived by vehicle owners that their vehicle will be selected for audit. Obviously, a program that inspects only a small percentage of the fleet will present only a small risk to vehicle owners who tamper.

As with change-of-ownership programs, vehicle owners cannot be expected to repair previous tampering until they are inspected. The following is an estimate of the percentage of the previously tampered vehicles in the fleet which would have been inspected at least once in the initial four years of the program depending on the audit rate. Audit rates greater than 5% are not considered feasible if audits are performed by random roadside pullover. Higher audit rates are feasible if the registration system is used to issue audit orders.

Pullover Rate	Percent of Previous Tampering Detected by January 1, 1988
1%	4%
2%	8%
5%	19%

For the previously tampered vehicles which are inspected, we will assume the same inspection effectiveness as for a biennial inspection.

In addition, it is assumed that some percentage of vehicle owners will not tamper after the program begins. The number of vehicle owners who do not tamper will depend on the visibility of the random audit inspection program, since it determines the perceived risk of detection. Visibility in turn will depend on the percentage of vehicles inspected each year. In this analysis we assume that if 5% of the fleet is inspected each year, the program will be 50% as effective as a biennial periodic inspection in deterring new tampering and misfueling. A 2% pullover program is assumed to be 35% as effective and a 1% program is assumed to be 25% as effective.

Visibility can be greatly enhanced by intense publicity and direct notification of vehicle owners. For example, if the registration system were used to issue audit orders, every vehicle owner could be notified by direct mail each year along with his or her renewal form that the audit program exists and that although his or her vehicle may not have been selected this year it may be next year, so tampering and misfueling in the coming year is ill-advised. This notice, personal accounts of friends and acquaintances who have been audited, and press coverage would make would-be tamperers well aware of the consequences. States using this approach; or a similarly effective publicity approach can be expected to achieve more credit than indicated by the above paragraph, and should consult EPA for specific estimates for their unique program designs.

Some of the new tampering that does occur will be detected and corrected, as with tampering that occurred prior to the start of the program. However, the percentage of the tampered fleet affected will be small due to the low audit rate, and deterrence will by far have the larger effect. For calculational simplicity, EPA has not accounted for the small benefit of detecting a few percent of the undeterred subsequent tampering and misfueling.

Tables 33 through 38 show the benefits of a random audit inspection program for these audit rates. Benefits are given for non-I/M areas and I/M areas separately. Benefits are shown for the several different inspection types covered in previous tables. The benefits are smaller than any of the programs presented earlier, due to less complete coverage and less effective deterrence. Although costs have not been calculated for this program, the cost of a roadside inspection including owner inconvenience is likely to be higher than an inspection at a licensed garage or state-run inspection station. Tending to counteract this is the fact that fewer inspections are performed and much of the benefit is from deterrence rather than correction. The cost per vehicle of centralized audits in response to registration based audit orders would be the same as in a periodic I/M program, but far fewer inspection stations would be needed. The overall result is that a registration based approach is likely to be highly cost-effective.

5.3.3 Fueling Station Enforcement Program

In this program, plain-clothes State or local enforcement officers would visit each fuel station unannounced to observe the fuelings that occur and to discover instances of the introduction of leaded fuel into catalyst equipped vehicles.

Responsibility for misfueling could be placed with the vehicle owner. The penalty could be mandatory replacement of the catalyst on that vehicle. A fine could be imposed if, within a reasonable period (i.e., one month) after the ticket had been issued, the catalyst had not been replaced. Court action to collect the fine could be started after a certain period. New license plates or renewal tags for that vehicle could also be denied until the catalyst had been replaced, as a back-up enforcement tool.

Federal law and regulation also prohibit station owners from introducing or allowing the introduction of leaded fuel into catalyst equipped vehicles. It would be possible to enact similar State prohibitions and enforce them to the extent practicable. Station personnel observed to allow the misfueling could also, then, be subject to a penalty.

Fuel station enforcement programs would most likely require new State or local regulations to be adopted to provide the implementing agency with the necessary authority. EPA believes that these approaches or similar ones would be a good deterrent to misfueling, if well publicized. However, no benefits are estimated in this report, since such benefits are highly dependent on the nature and aggressiveness of the specific State or local program. Areas interested in establishing fuel station enforcement programs are invited to discuss with EPA design criteria and emission reduction potential.

5.3.4 Other Approaches to Remove Incentives for and Aids to Tampering and Misfueling

Some portion of tampering and misfueling occurs in response to incentives that a jurisdiction can control. Limiting those incentives would reduce tampering and fuel switching without resort to a more negative enforcement/penalty approach. Even in cases in which a jurisdiction cannot effectively limit an incentive, it may be able to restrict the access to the means of tampering and misfueling, and thereby reduce their incidence without actually taking enforcement action against would-be tamperers or misfuelers. An example of the first approach would be equalization of the prices of leaded and unleaded gasoline, which would remove the immediate financial incentive to misfueling. An example of the second approach would be a ban on the sale of ready-made devices used to replace a removed catalyst; removal of a catalyst would then require more expensive custom fabrication of replacement exhaust piping, of which not every vehicle owner and small garage is capable. Other examples of the two approaches may also be possible.

EPA invites jurisdictions who are contemplating approaches in either or both categories to consult with EPA about the best design for the approach and the credits which would be available.

Table 27

Benefit of Annual Tampering Inspections in I/M Areas (January 1, 1988)

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi)					
		Passenger Car		Light-Duty Trucks (0-6000 lbs)		Light-Duty Trucks (6000-8500 lbs)	
		HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	4.74	106.10	13.04	291.65	3.07	68.74
	1980-1983	4.91	131.10	9.82	221.36	10.43	233.24
	1984+	1.15	36.99	1.54	37.46	1.87	45.36
Catalyst Only	Pre-1980	6.34	61.04	17.95	173.77	7.43	70.83
	1980-1983	5.11	65.37	26.09	257.99	29.53	283.99
	1984+	2.50	45.29	12.84	160.66	13.82	172.38
Air Pump & Catalyst	Pre-1980	11.37	173.50	31.72	481.77	10.88	148.03
	1980-1983	10.57	211.04	37.02	504.55	41.30	547.14
	1984+	3.78	86.54	14.65	204.90	16.01	225.55
Fuel Inlet & Catalyst	Pre-1980	21.25	178.97	55.19	461.68	23.11	188.88
	1980-1983	23.10	177.68	83.98	692.15	95.06	778.04
	1984+	13.06	110.66	49.23	424.73	53.35	458.77
Fuel Inlet & Catalyst & Air Pump	Pre-1980	26.90	305.37	71.00	815.33	27.65	290.44
	1980-1983	29.93	360.39	98.73	1025.11	111.32	1141.70
	1984+	14.76	165.41	52.65	508.36	57.31	555.60
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	32.98	267.82	87.75	707.38	36.50	286.71
	1980-1983	37.36	259.92	136.59	1087.71	151.31	1199.59
	1984+	37.08	274.44	91.38	742.81	97.45	790.36
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	39.38	410.91	105.70	1108.90	42.14	412.82
	1980-1983	45.55	478.81	154.52	1492.38	171.33	1647.36
	1984+	39.09	339.01	95.66	847.37	102.38	910.82
PCV*	Pre-1980	7.09	0.00	32.73	0.00	43.02	0.00
	1980-1983	5.80	0.00	22.17	0.00	34.69	0.00
	1984+	3.86	0.00	14.55	0.00	23.26	0.00
Evaporative* Canister	Pre-1980	3.02	0.00	20.26	0.00	4.95	0.00
	1980-1983	3.28	0.00	26.15	0.00	21.10	0.00
	1984+	1.55	0.00	18.47	0.00	15.35	0.00
All Items**	Pre-1980	49.49	410.91	158.69	1108.90	90.11	412.82
	1980-1983	54.63	478.81	202.84	1492.38	227.12	1647.36
	1984+	44.50	339.01	128.68	847.37	140.99	910.82
All Items**	All Years	148.62	1228.73	490.21	3448.65	458.22	2971.00
	(gm/mi)	(0.15)	(1.23)	(0.49)	(3.45)	(0.46)	(2.97)

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*PCV or evaporative canister benefits can be added directly to any of the above programs.

**Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 28

Benefit of Biennial Tampering Inspections in I/M Areas (January 1, 1988)

		Per Vehicle Reduction in Emissions (mg/mi)					
				Light-Duty Trucks			
	Affected						
Inspection	Model	Passenger Car		(0-6000 lbs)		(6000-8500 lbs)	
Program	Years	HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	4.15	92.84	11.41	255.19	2.69	60.14
	1980-1983	4.29	114.71	8.59	193.69	9.12	204.08
	1984+	1.01	32.37	1.35	32.78	1.63	39.69
Catalyst Only	Pre-1980	6.34	61.04	17.95	173.77	7.43	70.83
	1980-1983	5.11	65.37	26.09	257.99	29.53	283.99
	1984+	2.50	45.29	12.84	160.66	13.82	172.38
Air Pump & Catalyst	Pre-1980	10.74	159.44	30.00	443.27	10.45	138.38
	1980-1983	9.89	192.83	35.66	473.73	39.83	514.25
	1984+	3.62	81.38	14.43	199.37	15.74	218.90
Fuel Inlet & Catalyst	Pre-1980	21.25	178.97	55.19	461.68	23.11	188.88
	1980-1983	23.10	177.68	83.98	692.15	95.06	778.04
	1984+	13.06	110.66	49.23	424.73	53.35	458.77
Fuel Inlet & Catalyst & Air Pump	Pre-1980	26.27	291.32	69.28	776.83	27.22	280.79
	1980-1983	29.25	342.19	97.37	994.29	109.84	1108.81
	1984+	14.60	160.25	52.42	502.83	57.04	548.96
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	32.98	267.82	87.75	707.38	36.50	286.71
	1980-1983	37.36	259.92	136.59	1087.71	151.31	1199.59
	1984+	37.08	274.44	91.38	742.81	97.45	790.36
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	38.63	394.18	103.60	1062.38	41.51	398.84
	1980-1983	44.58	452.96	152.44	1445.78	169.01	1595.94
	1984+	38.84	330.94	95.12	834.30	101.76	895.76
PCV*	Pre-1980	4.83	0.00	22.32	0.00	29.33	0.00
	1980-1983	3.95	0.00	15.12	0.00	23.65	0.00
	1984+	2.63	0.00	9.92	0.00	15.86	0.00
Evaporative* Canister	Pre-1980	2.11	0.00	14.14	0.00	3.46	0.00
	1980-1983	2.29	0.00	18.25	0.00	14.72	0.00
	1984+	1.08	0.00	12.88	0.00	10.71	0.00
All Items**	Pre-1980	45.57	394.22	140.06	1062.56	74.30	398.93
	1980-1983	50.82	453.02	185.80	1446.03	207.38	1596.21
	1984+	42.55	330.94	117.92	834.30	128.33	895.76
All Items**	All Years (gm/mi)	138.94 (0.14)	1178.18 (1.18)	443.78 (0.44)	3342.89 (3.34)	410.01 (0.41)	2890.90 (2.89)

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*PCV or evaporative canister benefits can be added directly to any of the above programs.

**Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 29

Benefit of Annual Tampering Inspections in Non-I/M Areas (January 1, 1988)

		Per Vehicle Reduction in Emissions (mg/mi)					
		Passenger Car		Light-Duty Trucks (0-6000 lbs)		Light-Duty Trucks (6000-8500 lbs)	
Inspection Program	Affected Model Years	HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	10.75	240.50	35.47	793.58	8.05	180.18
	1980-1983	10.82	289.07	28.03	632.34	28.98	648.20
	1984+	2.59	83.14	7.05	173.27	7.98	196.08
Catalyst Only	Pre-1980	20.25	198.29	67.12	658.90	27.88	270.51
	1980-1983	15.78	206.64	98.60	985.86	111.46	1085.66
	1984+	5.54	100.38	49.50	617.57	53.23	662.24
Air Pump & Catalyst	Pre-1980	31.67	453.73	104.70	1499.50	37.03	475.20
	1980-1983	27.87	529.83	130.09	1696.40	144.51	1825.13
	1984+	8.42	193.06	57.80	821.84	62.59	892.55
Fuel Inlet & Catalyst	Pre-1980	35.83	318.50	110.58	978.90	45.78	396.61
	1980-1983	32.21	300.76	162.53	1434.32	183.05	1590.13
	1984+	14.93	157.44	84.02	843.04	90.61	906.54
Fuel Inlet & Catalyst & Air Pump	Pre-1980	48.12	593.43	151.69	1898.54	56.80	643.04
	1980-1983	46.03	670.25	200.43	2289.87	223.56	2496.33
	1984+	18.23	263.50	95.28	1121.21	103.17	1216.88
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	83.50	683.63	231.63	1864.93	95.57	744.73
	1980-1983	84.50	597.15	341.38	2689.29	382.67	2993.91
	1984+	53.02	397.17	193.09	1574.45	207.99	1692.70
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	98.57	1020.73	282.75	3008.50	111.83	1108.59
	1980-1983	103.69	1109.97	396.61	3936.47	443.43	4353.06
	1984+	57.58	543.48	211.94	2041.96	228.83	2209.07
PCV*	Pre-1980	7.09	0.00	32.73	0.00	43.02	0.00
	1980-1983	5.80	0.00	22.17	0.00	34.69	0.00
	1984+	3.86	0.00	14.55	0.00	23.26	0.00
Evaporative* Canister	Pre-1980	3.02	0.00	20.26	0.00	4.95	0.00
	1980-1983	3.28	0.00	26.15	0.00	21.10	0.00
	1984+	1.55	0.00	18.47	0.00	15.35	0.00
All Items**	Pre-1980	108.68	1020.73	335.74	3008.50	159.80	1108.59
	1980-1983	112.77	1109.97	444.93	3936.47	499.22	4353.06
	1984+	62.99	543.48	244.96	2041.96	267.44	2209.07
All Items**	All Years (gm/mi)	284.44 (0.28)	2674.18 (2.67)	1025.63 (1.03)	8986.93 (8.99)	926.46 (0.93)	7670.72 (7.67)

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*PCV or evaporative canister benefits can be added directly to any of the above programs.

**Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 30

Benefit of Biennial Tampering Inspections in Non-I/M Areas (January 1, 1988)

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi)					
		Passenger Car		Light-Duty Trucks			
				(0-6000 lbs)		(6000-8500 lbs)	
		HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	9.41	210.44	31.04	694.39	7.05	157.66
	1980-1983	9.47	252.94	24.52	553.30	25.35	567.18
	1984+	2.26	72.75	6.17	151.61	6.98	171.57
Catalyst Only	Pre-1980	20.25	198.29	67.12	658.90	27.88	270.51
	1980-1983	15.78	206.64	98.60	985.86	111.46	1085.66
	1984+	5.54	100.38	49.50	617.57	53.23	662.24
Air Pump & Catalyst	Pre-1980	30.24	421.80	100.00	1394.42	35.89	449.61
	1980-1983	26.36	489.43	126.15	1607.58	140.38	1732.69
	1984+	8.06	181.47	56.76	796.30	61.42	863.76
Fuel Inlet & Catalyst	Pre-1980	35.83	318.50	110.58	978.90	45.78	396.61
	1980-1983	32.21	300.76	162.53	1434.32	183.05	1590.13
	1984+	14.93	157.44	84.02	843.04	90.61	906.54
Fuel Inlet & Catalyst & Air Pump	Pre-1980	46.35	558.62	145.13	1777.61	54.71	609.43
	1980-1983	44.11	626.58	193.54	2176.18	216.16	2376.13
	1984+	17.87	251.91	93.85	1092.55	101.60	1184.79
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	83.50	683.63	231.63	1864.93	95.57	744.73
	1980-1983	84.50	597.15	341.38	2689.29	382.67	2993.91
	1984+	53.02	397.17	193.09	1574.45	207.99	1692.70
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	96.83	981.68	276.95	2878.79	110.10	1069.69
	1980-1983	101.43	1049.46	390.52	3798.95	436.75	4203.84
	1984+	57.01	525.19	209.66	1985.38	226.30	2146.50
PCV*	Pre-1980	4.83	0.00	22.32	0.00	29.33	0.00
	1980-1983	3.95	0.00	15.11	0.00	23.65	0.00
	1984+	2.63	0.00	9.92	0.00	15.86	0.00
Evaporative* Canister	Pre-1980	2.11	0.00	14.14	0.00	3.46	0.00
	1980-1983	2.29	0.00	18.25	0.00	14.72	0.00
	1984+	1.08	0.00	12.88	0.00	10.71	0.00
All Items**	Pre-1980	103.77	981.68	313.41	2878.79	142.89	1069.69
	1980-1983	107.67	1049.46	423.88	3798.95	475.12	4203.84
	1984+	60.72	525.19	232.46	1985.38	252.87	2146.50
All Items**	All Years	272.16	2556.33	969.75	8663.12	870.88	7420.03
	(gm/mi)	(0.27)	(2.56)	(0.97)	(8.66)	(0.87)	(7.42)

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*PCV or evaporative canister benefits can be added directly to any of the above programs.

**Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 31

Benefit of Tampering Inspections At Change of Ownership in Non-I/M Areas* (January 1, 1988)

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi) Passenger Car HC	Passenger Car CO	Light-Duty Trucks (0-6000 lbs) HC	Light-Duty Trucks (0-6000 lbs) CO	Light-Duty Trucks (6000-8500 lbs) HC	Light-Duty Trucks (6000-8500 lbs) CO
Air Pump Only	Pre-1980	6.05	135.24	19.34	432.64	4.78	106.97
	1980-1983	7.67	206.95	18.98	428.62	20.10	449.57
	1984+	2.26	72.75	6.14	150.93	6.95	170.79
Catalyst Only	Pre-1980	13.44	131.63	39.32	384.71	16.76	161.79
	1980-1983	13.12	175.56	63.43	630.24	72.64	702.14
	1984+	5.54	100.38	45.33	567.74	48.83	609.56
Air Pump & Catalyst	Pre-1980	19.87	275.47	59.82	843.28	22.17	282.80
	1980-1983	21.70	407.10	84.64	1109.42	95.40	1211.23
	1984+	8.06	181.47	52.52	744.66	56.94	809.09
Fuel Inlet & Catalyst	Pre-1980	23.91	212.40	65.83	579.96	28.03	241.21
	1980-1983	26.90	253.78	107.21	937.48	122.29	1052.29
	1984+	14.93	157.44	77.46	777.39	83.67	837.12
Fuel Inlet & Catalyst & Air Pump	Pre-1980	30.76	367.95	87.54	1078.63	34.13	384.39
	1980-1983	36.72	522.67	131.32	1503.11	148.55	1662.58
	1984+	17.87	251.91	87.20	1021.34	94.55	1109.42
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	54.53	445.83	138.23	1106.85	58.68	453.58
	1980-1983	67.08	472.64	226.25	1760.98	256.81	1985.57
	1984+	51.92	389.22	179.04	1455.67	193.14	1567.10
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	63.15	638.84	166.30	1734.83	68.19	666.28
	1980-1983	80.85	844.08	262.34	2576.89	297.13	2887.48
	1984+	55.90	517.24	194.91	1849.47	210.70	2002.70
All Items**	All Years	199.90	2000.16	623.55	6161.19	576.02	5556.46
	(gm/mi)	(0.20)	(2.00)	(0.62)	(6.16)	(0.58)	(5.56)

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*Assumes a random 15% changeover of the fleet each year with program beginning January 1, 1984.

**Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 32

Benefit of Tampering Inspections At Change of Ownership in I/M Areas* (January 1, 1988)

		Per Vehicle Reduction in Emissions (mg/mi)					
				Light-Duty Trucks			
Inspection Program	Affected Model Years	Passenger Car		(0-6000 lbs)		(6000-8500 lbs)	
		HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	2.67	59.78	7.42	165.88	1.93	43.15
	1980-1983	3.50	94.27	7.28	164.26	7.87	176.11
	1984+	1.01	32.37	1.35	32.78	1.63	39.69
Catalyst Only	Pre-1980	4.09	39.31	10.59	101.77	4.50	42.41
	1980-1983	3.98	51.50	16.96	165.20	19.45	183.86
	1984+	2.50	45.29	11.79	148.00	12.72	158.98
Air Pump & Catalyst	Pre-1980	3.53	73.91	7.91	187.78	2.61	56.37
	1980-1983	6.06	141.96	12.24	239.55	14.37	263.37
	1984+	3.62	81.38	11.52	171.61	12.66	189.55
Fuel Inlet & Catalyst	Pre-1980	14.76	123.90	35.06	291.10	15.18	122.86
	1980-1983	19.64	149.48	60.10	487.15	68.85	554.80
	1984+	13.06	110.66	46.49	398.30	50.45	430.81
Fuel Inlet & Catalyst & Air Pump	Pre-1980	18.03	197.04	44.23	496.22	18.07	187.64
	1980-1983	24.67	285.35	71.12	736.17	81.18	830.69
	1984+	14.60	160.25	49.68	476.41	54.14	521.00
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	20.12	162.65	50.08	399.36	21.27	164.23
	1980-1983	25.72	174.44	83.72	649.35	93.89	724.18
	1984+	34.70	257.35	83.59	675.51	89.22	719.23
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	23.77	244.26	60.33	628.65	24.73	241.72
	1980-1983	31.56	331.80	96.55	939.41	108.39	1048.47
	1984+	36.46	313.85	87.33	767.00	93.53	824.63
All Items**	All Years	91.79	889.91	244.21	2335.06	226.65	2114.82
	(gm/mi)	(0.09)	(0.89)	(0.24)	(2.34)	(0.23)	(2.11)

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*Assumes a random 15% changeover of the fleet each year with program beginning January 1, 1984.

**Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 33

Benefit of Anti-Tampering Inspections During 5% Random Audit Non-I/M Areas

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi)					
				Light-Duty Trucks			
		Passenger Car		(0-6000 lbs)		(6000-8500 lbs)	
		HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	2.65	59.27	8.37	187.24	2.14	47.86
	1980-1983	3.64	98.37	8.87	200.46	9.46	211.72
	1984+	1.13	36.38	3.07	75.39	3.47	85.31
Catalyst Only	Pre-1980	6.06	59.38	16.89	165.05	7.28	70.12
	1980-1983	6.34	85.38	28.28	280.40	32.55	313.74
	1984+	2.80	50.72	22.46	281.53	24.20	302.35
Air Pump & Catalyst	Pre-1980	8.88	122.45	25.77	363.56	9.70	124.17
	1980-1983	10.41	195.45	38.18	504.15	43.25	552.95
	1984+	4.06	91.27	26.04	369.79	28.25	401.90
Fuel Inlet & Catalyst	Pre-1980	10.71	95.22	28.18	248.19	12.14	104.41
	1980-1983	12.93	122.66	47.83	417.57	54.82	470.85
	1984+	7.49	79.25	38.25	384.51	41.33	414.18
Fuel Inlet & Catalyst & Air Pump	Pre-1980	15.56	197.43	42.80	560.74	16.94	202.46
	1980-1983	22.97	345.64	69.50	857.36	78.98	952.42
	1984+	11.22	168.51	49.10	600.20	53.46	655.80
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	24.45	199.85	59.84	478.11	25.70	198.03
	1980-1983	32.05	225.58	102.02	790.57	116.32	895.52
	1984+	26.14	195.98	89.04	723.27	96.08	778.88
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	28.01	282.69	70.68	738.30	29.25	286.38
	1980-1983	38.30	400.05	116.58	1148.74	132.69	1293.12
	1984+	28.13	259.99	96.62	916.11	104.49	992.38
All Items*	All Years	94.44	942.73	283.88	2803.15	266.43	2571.88
	(gm/mi)	(0.09)	(0.94)	(0.28)	(2.80)	(0.27)	(2.57)

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*Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 34

Benefit of Anti-Tampering Inspections During 2% Random Audit in Non-I/M Areas

		Per Vehicle Reduction in Emissions (mg/mi)					
				Light-Duty Trucks			
		Passenger Car		(0-6000 lbs)		(6000-8500 lbs)	
Inspection Program	Affected Model Years	HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	1.49	33.38	4.59	102.59	1.26	28.15
	1980-1983	2.38	64.79	5.68	128.34	6.13	137.23
	1984+	0.81	25.98	2.19	53.77	2.48	60.84
Catalyst Only	Pre-1980	3.42	33.51	8.57	83.40	3.78	36.28
	1980-1983	4.07	55.29	15.59	153.77	18.12	173.63
	1984+	1.92	34.87	14.98	188.09	16.15	202.09
Air Pump & Catalyst	Pre-1980	5.01	69.08	13.43	192.22	5.20	67.97
	1980-1983	6.74	127.81	21.90	296.61	25.03	328.07
	1984+	2.82	63.83	17.54	250.91	19.03	272.96
Fuel Inlet & Catalyst	Pre-1980	6.31	55.82	15.25	132.63	6.73	57.05
	1980-1983	8.62	80.94	28.07	241.39	32.44	274.65
	1984+	5.37	55.79	26.35	262.21	28.49	282.63
Fuel Inlet & Catalyst & Air Pump	Pre-1980	8.02	94.69	20.42	251.55	8.33	94.56
	1980-1983	11.72	166.02	35.27	409.27	40.41	458.72
	1984+	6.42	89.66	29.82	348.88	32.37	379.39
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	14.11	114.98	32.19	255.07	14.15	107.89
	1980-1983	20.58	144.08	59.30	454.38	68.16	519.16
	1984+	18.10	135.45	60.48	489.62	65.29	527.50
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	16.00	160.82	37.34	390.39	15.81	155.32
	1980-1983	24.55	258.13	67.30	668.05	77.27	758.46
	1984+	19.53	181.17	65.70	624.42	71.10	676.88
All Items*	All Years	60.08	600.12	170.34	1682.86	164.18	1590.66
	(gm/mi)	(0.06)	(0.60)	(0.17)	(1.68)	(0.16)	(1.59)

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*Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 35

Benefit of Anti-Tampering Inspections During 1% Random Roadside Audit in Non-I/M Areas

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi)					
		Passenger Car		Light-Duty Trucks (0-6000 lbs)		Light-Duty Trucks (6000-8500 lbs)	
		HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	1.02	22.78	3.11	69.50	0.87	19.42
	1980-1983	1.69	45.88	3.99	90.33	4.33	96.84
	1984+	0.58	18.71	1.57	38.71	1.78	43.79
Catalyst Only	Pre-1980	2.33	22.89	5.61	54.55	2.51	23.96
	1980-1983	2.90	39.52	10.55	103.91	12.32	117.73
	1984+	1.40	25.36	10.81	135.68	11.65	145.80
Air Pump & Catalyst	Pre-1980	3.42	47.17	8.91	128.29	3.48	45.82
	1980-1983	4.79	90.88	14.99	204.39	17.18	226.64
	1984+	2.05	46.21	12.64	180.88	13.72	196.79
Fuel Inlet & Catalyst	Pre-1980	4.26	37.78	9.67	84.54	4.33	36.87
	1980-1983	6.14	57.81	18.60	160.45	21.60	183.38
	1984+	3.90	40.58	18.93	188.66	20.47	203.39
Fuel Inlet & Catalyst & Air Pump	Pre-1980	5.46	64.47	13.30	165.55	5.50	62.92
	1980-1983	8.37	118.32	23.84	278.93	27.43	313.62
	1984+	4.66	65.00	21.46	251.17	23.30	273.18
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	9.14	74.65	20.13	159.83	8.97	68.48
	1980-1983	14.00	98.80	38.69	296.72	44.66	340.39
	1984+	12.69	95.52	42.35	344.63	45.72	371.35
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	10.61	107.53	24.60	259.75	10.61	105.27
	1980-1983	17.04	181.41	45.89	459.67	52.83	523.17
	1984+	13.71	128.44	46.31	443.16	50.12	480.46
All Items*	All Years	41.36	417.38	116.80	1162.58	113.56	1108.90
	(gm/mi)	(0.04)	(0.42)	(0.12)	(1.16)	(0.11)	(1.11)

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*Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 36

Benefit of Anti-Tampering Inspections During 5% Random Audit in I/M Areas

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi) Passenger Car HC	Passenger Car CO	Light-Duty Trucks (0-6000 lbs) HC	(0-6000 lbs) CO	(6000-8500 lbs) HC	(6000-8500 lbs) CO
Air Pump Only	Pre-1980	1.17	26.22	3.26	73.02	0.88	19.69
	1980-1983	1.66	44.86	3.49	78.86	3.80	84.95
	1984+	0.50	16.18	0.67	16.39	0.82	19.84
Catalyst Only	Pre-1980	1.83	17.54	4.56	43.72	1.96	18.39
	1980-1983	1.89	24.54	7.59	73.55	8.75	82.18
	1984+	1.26	22.88	5.85	73.43	6.31	78.89
Air Pump & Catalyst	Pre-1980	3.07	45.37	8.01	120.91	2.94	40.38
	1980-1983	3.73	74.33	11.46	160.99	13.00	177.36
	1984+	1.82	40.93	6.64	92.78	7.27	102.16
Fuel Inlet & Catalyst	Pre-1980	6.71	56.23	15.43	127.76	6.76	54.56
	1980-1983	9.47	71.99	27.59	222.48	31.73	254.45
	1984+	6.54	55.57	23.02	197.14	24.99	213.28
Fuel Inlet & Catalyst & Air Pump	Pre-1980	8.15	88.48	19.47	218.24	8.08	84.00
	1980-1983	11.86	136.78	32.85	341.30	37.63	386.53
	1984+	7.31	80.36	24.61	236.19	26.83	258.38
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	8.79	70.92	21.27	168.78	9.11	69.86
	1980-1983	11.76	78.99	36.64	281.15	41.29	315.00
	1984+	17.30	128.32	41.44	334.38	44.24	356.08
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	10.31	106.09	25.42	266.52	10.50	103.28
	1980-1983	14.39	152.73	42.24	414.57	47.65	464.59
	1984+	18.18	156.56	43.31	380.13	46.39	408.78
All Items*	All Years	42.88	415.38	110.97	1061.22	104.54	976.65
	(gm/mi)	(0.04)	(0.42)	(0.11)	(1.06)	(0.10)	(0.98)

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*Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 37

Benefit of Anti-Tampering Inspections During 2% Random Audit in I/M Areas

		Per Vehicle Reduction in Emissions (mg/mi)					
				Light-Duty Trucks			
		Passenger Car		(0-6000 lbs)		(6000-8500 lbs)	
Inspection Program	Affected Model Years	HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	0.66	14.79	1.86	41.53	0.54	12.04
	1980-1983	1.09	29.61	2.34	52.83	2.56	57.35
	1984+	0.36	11.56	0.48	11.71	0.58	14.17
Catalyst Only	Pre-1980	1.01	9.67	2.33	22.16	1.02	9.53
	1980-1983	1.17	15.35	4.22	40.38	4.91	45.52
	1984+	0.87	15.73	3.91	49.09	4.22	52.77
Air Pump & Catalyst	Pre-1980	1.71	25.39	4.29	66.09	1.62	22.94
	1980-1983	2.38	48.20	6.80	98.86	7.77	109.62
	1984+	1.27	28.62	4.47	62.91	4.90	69.39
Fuel Inlet & Catalyst	Pre-1980	4.14	34.53	9.02	73.96	4.04	32.23
	1980-1983	6.39	48.04	17.26	137.36	19.96	158.25
	1984+	4.64	39.08	16.02	136.28	17.40	147.51
Fuel Inlet & Catalyst & Air Pump	Pre-1980	4.97	53.04	11.35	125.98	4.84	50.27
	1980-1983	7.98	91.11	20.76	216.49	23.92	246.72
	1984+	5.19	56.79	17.16	164.17	18.72	179.72
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	4.84	38.86	11.06	86.61	4.83	36.35
	1980-1983	7.04	46.42	20.26	151.84	23.04	171.69
	1984+	11.83	87.64	28.09	225.88	29.99	240.58
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	5.66	58.37	13.21	140.22	5.56	55.47
	1980-1983	8.71	94.43	23.70	237.32	26.97	268.04
	1984+	12.45	107.81	29.42	258.55	31.53	278.22
All Items*	All Years	26.82	260.61	66.33	636.09	64.06	601.73
	(gm/mi)	(0.03)	(0.26)	(0.07)	(0.64)	(0.06)	(0.60)

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*Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

Table 38

Benefit of Anti-Tampering Inspections During 1% Random Audit in I/M Areas

Inspection Program	Affected Model Years	Per Vehicle Reduction in Emissions (mg/mi)					
		Passenger Car		Light-Duty Trucks (0-6000 lbs)		Light-Duty Trucks (6000-8500 lbs)	
		HC	CO	HC	CO	HC	CO
Air Pump Only	Pre-1980	0.45	10.10	1.27	28.41	0.37	8.39
	1980-1983	0.77	20.98	1.66	37.55	1.82	40.82
	1984+	0.26	8.32	0.35	8.43	0.42	10.21
Catalyst Only	Pre-1980	0.68	6.55	1.53	14.51	0.68	6.30
	1980-1983	0.83	10.85	2.86	27.30	3.34	30.88
	1984+	0.63	11.44	2.82	35.42	3.04	38.08
Air Pump & Catalyst	Pre-1980	1.16	17.29	2.87	44.57	1.10	15.63
	1980-1983	1.68	34.13	4.70	68.86	5.38	76.48
	1984+	0.92	20.72	3.23	45.38	3.53	50.05
Fuel Inlet & Catalyst	Pre-1980	2.68	22.43	5.58	45.86	2.55	20.36
	1980-1983	4.45	33.53	11.38	90.40	13.23	104.65
	1984+	3.35	28.25	11.44	97.40	12.43	105.45
Fuel Inlet & Catalyst & Air Pump	Pre-1980	3.24	34.93	7.15	80.87	3.10	32.60
	1980-1983	5.56	63.82	13.82	145.75	15.99	166.60
	1984+	3.74	41.00	12.27	117.48	13.38	128.64
Plumbtesmo & Fuel Inlet & Catalyst	Pre-1980	3.04	24.42	6.71	52.37	2.96	22.18
	1980-1983	4.61	30.40	12.75	94.69	14.58	107.65
	1984+	8.23	61.25	19.54	157.49	20.86	167.77
Plumbtesmo & Fuel Inlet & Catalyst & Air Pump	Pre-1980	3.66	38.25	8.45	91.25	3.61	36.56
	1980-1983	5.89	65.17	15.56	158.39	17.79	179.50
	1984+	8.68	75.78	20.50	181.01	21.97	194.87
All Items*	All Years (gm/mi)	18.23 (0.02)	179.20 (0.18)	44.51 (0.04)	430.65 (0.43)	43.37 (0.04)	410.93 (0.41)

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*Plumbtesmo, fuel inlet, catalyst, air pump, PCV and evaporative canister checks.

6.0 ADJUSTMENT TO LOCAL CONDITIONS: USE OF MOBILE3 TO CALCULATE PROGRAM BENEFITS

All of the tables in this report assume standard FTP ambient conditions and use national average fleet descriptors. As a result, the emission reductions estimated must only be compared to emission levels for cars and trucks which were also estimated for standard conditions using national averages.

Although this report has extensive tables which provide the emission reductions estimated for various anti-tampering and anti-misfueling programs, it is likely that, in many cases, the particular inspection scenario preferred by a local area may differ from any of the scenarios provided in the tables. For example, all of the tables assume an inspection program begins on January 1, 1984. If an area has already begun the inspection program before that date or will not have started inspections until later, then the tables provided in this report will not accurately match the needs of the user. Also, local conditions such as vehicle model year registration distributions or tampering and misfueling rates which differ significantly from the national averages may make the estimates in the table inappropriate for a local area. Care should therefore be used when using the tables in this report to estimate potential emission reduction benefits from inspection programs.

The upcoming MOBILE3 emission factor model, used by EPA and most areas to predict emission levels from highway mobile sources, includes the effects of tampering and misfueling using the assumptions and estimates developed for this report. The model also incorporates the capability to adjust these emission estimates for local conditions. As a result, MOBILE3 is ideally suited to predict the potential emission reduction benefits for areas which have local conditions which differ from national averages.

MOBILE3 also allows users to obtain the emission reductions due to inspection programs by selecting the appropriate inspection program options entering the inspection program parameters, and providing a set of emission reduction effectiveness factors. MOBILE3, as released, will not contain these emission reduction effectiveness factors, since they will depend on so many variables that MOBILE3 could not reasonably store them all. EPA is prepared, however, to provide these factors to MOBILE3 users for any specific inspection program scenario specified by a local area. If preferable, a local area may request that EPA estimate the emission reductions. Local areas should not attempt to estimate the emission reduction factors for themselves.

Once the inspection program parameters, local conditions, and emission reduction factors have been input into MOBILE3, users will be able to use the MOBILE3 output directly in SIP calculations. If MOBILE3 is not available, local areas should consult with EPA on the appropriate method to adjust mobile source emission estimates to account for an inspection program.

Once MOBILE3 output reflecting an anti-tampering/anti-misfueling program has been obtained, it can be used in SIP inventory calculations in exactly the same manner as normal MOBILE3 output. The incremental effect of the anti-tampering/anti-misfueling program can be determined by using MOBILE3 to calculate two inventories, one with and one without the program. By subtracting one from the other, the user will be able to identify the credit attributable to the program.

For example, an area using MOBILE3 predicts a 25.00 gm/mi highway mobile source composite CO emission factor in a particular evaluation year without a tampering inspection program. It predicts a 23.00 gm/mi CO emission factor using the EPA supplied emission reduction factors specific to the proposed tampering inspection program. The incremental benefit of the inspection program is therefore 2.00 gm/mi CO. In this area, the highway mobile source CO inventory is 1000 tons per day at 25 gm/mi without the inspection program. The incremental benefit of the inspection program in tons is therefore:

$$(2.00/25.00) * 1000 \text{ tons/day} = 80 \text{ tons/day}$$

All of the tables in this report contain the incremental benefits of the various programs in milligrams per mile. If the incremental benefit of an inspection program is needed in tons and MOBILE3 is not available, the tables in this report can be used to estimate the benefit, if the program parameters (i.e., start date) do not differ significantly from the parameters assumed for the tables.

First the separate mg/mi benefits for LDV, LDT1, LDT2 must be combined into a single mg/mi benefit from mobile sources. For example, if the tables show a 2330 mg/mi CO benefit for LDV, a 3000 mg/mi CO benefit for LDT1 and a 2500 mg/mi CO benefit for LDT2 for a proposed tampering inspection program, the three benefits must first be combined. This is done by weighting the benefit from each vehicle type by the fraction of the total VMT (vehicle mileage traveled) contributed by each of the vehicle types to the composite VMT for all highway mobile sources. In this example, let's assume that LDV accounts for 70% of all VMT by highway mobile sources and LDT1 and LDT2 each contribute 8% and 5%.

The composite benefit would therefore be:

(2330 * 0.70) + (3000 * 0.08) + (2500 * 0.05) = 2000 mg/mi CO.

This 2000 mg/mi is then converted (by dividing by 1000) to give 2.00 grams per mile to be compared to MOBILE2 output which is reported in grams per mile.

Second the benefits in the tables in this report must be adjusted for local conditions. This can be roughly estimated by comparing the mobile source composite emission factor used to compile the inventory to the composite emission factor that would result if FTP ambient conditions and national average fleet descriptors had been used. For example, if MOBILE2 were used to compile a January 1, 1988 CO inventory, the local composite emission factor would be compared to the 27.84 gm/mi predicted by MOBILE2 using FTP conditions and national averages.

If, for example, the local area used MOBILE2 with alternate vehicle registration distributions and non-FTP conditions to estimate the mobile source inventory on January 1, 1988, with a resultant 25.00 gm/mi composite CO emission factor, all the benefits in the tables in this report must be adjusted by the factor 25.00/27.84 to roughly correct for the effect of local conditions on the benefits.

2000 * (25.00/27.84) = 1.80 gm/mi.

Next, as with the incremental benefit estimated by MOBILE3, the adjusted benefit from the tables is divided by the composite emission factor used to estimate the inventory and then multiplied by the inventory in tons. The result is an approximation of the incremental benefit in tons. A better estimate is provided by using MOBILE3 using the method outlined above.

(1.80/25.00) * 1000 tons/day = 72 tons/day.

Benefits in tons can also be estimated by multiplying the adjusted mobile source composite benefit (200 mg/mi) by an average VMT figure. The VMT figure must be for all highway vehicles in the appropriate geographic area for the appropriate time interval. The VMT figure must also be consistent with the VMT figures used to prepare other portions of the SIP inventory.

Again, if there are significant differences between local conditions, tampering rates and vehicles and the national averages and assumptions used in this report, then the tables provided will not be useful to accurately estimate the benefits of tampering inspection programs. In these cases, EPA should be consulted either to provide the emission reduction factors for use in MOBILE3 or to make the estimates.

References

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2. "Evaluation of the Applicability of a Lead-Sensitive Test Paper as a Diagnostic Tool for Detecting Habitual Misfueling of Catalyst-Equipped Motor Vehicles." Technical Report. Bill Smuda, U.S. EPA, I/M Staff. July 1980.

3. "Assessment of Current and Projected Future Trends in Light-Duty Vehicle Fuel Switching," Energy and Environmental Analysis, Inc., Arlington, Virginia. June 1982.

4. "1968-1982 Automotive Emission Systems Application Guide," Department of Industrial Sciences, Colorado State University, Ft. Collins, Colorado.

5. "Compilation of Air Pollutant Emission Factors: Highway Mobile Sources," U.S. EPA Emission Control Technology Division, March 1981. (EPA460/3-81-005).

6. 1981 Wards Automotive Yearbook, Ward's Communications, Inc. Detroit, Michigan. Library of Congress Number 40-33639.

APPENDIX

Disablement Data Base

(EPA-AA-TSS-83-10)

Table A-1: Air Pump (Oxidation Catalyst)
Table A-2: Air Pump (Three-way Catalyst)
Table A-3: Catalyst (Oxidation Catalyst)
Table A-4: Catalyst (Three-way Catalyst)
Table A-5: Misfueling (Oxidation Catalyst)
Table A-6: Misfueling (Three-way Catalyst)
Table A-7: EGR (Pre-Catalyst)
Table A-8: EGR (3.1 Std.) Oxidation Catalyst
Table A-9: EGR (2.0 Std.) Oxidation Catalyst
Table A-10: EGR (1.0 Std.) Three-Way Catalyst
Table A-11: Oxygen Sensor
Table A-12: Evaporative Canister
References

Table A-1

Air Pump Disablement Testing of Oxidation Catalyst Vehicles

Site*	Vehicle Number	Model Year	Manufacturer	Test	Condition	FTP (gm/mi)	
						HC	CO
Chicago	6034	1976	Ford	4	Ok	0.61	2.72
				7	Disabled	2.72	34.74
Chicago	5035	1975	Ford	2	Ok	0.75	4.43
				7	Disabled	2.23	46.54
Chicago	6041	1976	Ford	1	Ok	0.71	1.44
				7	Disabled	2.03	21.30
Chicago	6050	1976	Ford	4	Ok	1.31	8.66
				9	Disabled	1.63	16.67
Chicago	6062	1976	Ford	4	Ok	0.67	4.44
				6	Disabled	0.94	19.89
Washington	6052	1976	Ford	4	Ok	0.64	11.05
				7	Disabled	0.69	15.25
Washington	6060	1976	Ford	4	Ok	1.09	2.99
				7	Disabled	2.72	30.77
Washington	6073	1976	GM	4	Ok	0.55	7.74
				8	Disabled	0.87	13.66
San Francisco	6003	1976	Chrysler	1	Ok	0.68	8.65
				8	Disabled	4.89	83.18
San Francisco	6010	1976	Chrysler	1	Ok	0.46	5.83
				7	Disabled	2.37	40.35
San Francisco	6012	1976	Chrysler	2	Ok	0.48	7.27
				9	Disabled	2.90	78.17
San Francisco	6036	1976	Ford	2	Ok	0.70	3.83
				7	Disabled	1.99	41.52
San Francisco	6039	1976	Ford	1	Ok	0.45	1.52
				9	Disabled	0.99	26.42
Averages					Ok	0.70	5.43
					Disabled	2.07	36.04
				Average Excess		1.37	30.61

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*Vehicles from Restorative Maintenance (RM76) Programs (see References).

Table A-2

Air Pump Disablement Testing of Three-Way Catalyst Vehicles

Program*	Model Year	Manufacturer	Vehicle ID (if any)	Condition	FTP (gm/mi) HC	FTP (gm/mi) CO
LA80	1980	Ford	#46	Ok	0.24	1.41
				Disabled	0.90	24.56
MVEL	1979	Ford	-	Ok	0.24	1.33
				Disabled	0.69	10.70
MVEL	1979	Chrysler	-	Ok	0.41	4.10
				Disabled	1.03	29.80
GM	(Prototype)	GM	-	Ok	0.23	1.40
				Disabled	0.52	8.32
Averages				Ok	0.28	2.06
				Disabled	0.79	18.35
				Average Excess	0.51	16.29

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*Programs listed in references.

Table A-3

Catalyst Removal Disablement Testing of Oxidation Catalyst Vehicles

Program*	Vehicle Number	Model Year	Manufacturer	Condition	FTP (gm/mi) HC	FTP (gm/mi) CO
STL	9401	1979	Ford	Ok	0.67	6.77
				Bypassed	3.48	32.50
STL	9402	1979	Ford	Ok	0.91	3.67
				Bypassed	3.54	13.10
STL	9403	1979	GM	Ok	0.54	3.57
				Bypassed	1.99	7.20
STL	9404	1979	GM	Ok	0.87	12.47
				Bypassed	2.55	14.35
Averages				Ok	0.75	6.62
				Bypassed	2.89	16.79
				Average Excess	2.14	10.17

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*Programs listed in references.

Excess Calculation:

((2.89/0.75)-1.0)* 1.07 = 3.05 gm/mi HC

((16.79/6.62)-1.0)* 18.23 = 28.01 gm/mi CO

This calculation increases the MOBILE3 estimate of zero-mile emissions for oxidation catalyst technology vehicles by the percentage increase in emissions from catalyst removal to give the excess emissions used in this report.

Data Point Selection Criteria

1. Vehicles which were designed to California standards were considered acceptable for estimating the effects of disablement on similar federal certified vehicles.

2. Whenever possible, only testing of 1981 and later closed-loop vehicles was used to estimate the effects of disablements on closed-loop vehicles. Existing data on prototype vehicles were not used, except in the case of air pump disablements.

3. Both deliberate disablement testing program results and repair of in-use disablements were considered acceptable for estimating the effects of disablements. Multiple repair or disablement results were not used.

4. Whenever more than one test was conducted in a particular mode, the average of all tests was used to establish the emission levels of that mode.

5. Engine-out emissions and emissions measured with a catalyst bypass were considered acceptable for estimating the effects of catalyst removal.

6. The last test run using leaded fuel was used to establish the misfueled case for emission levels.

7. When data sample size allowed, only deliberate disablement results were used to determine the excess emissions of a particular disablement.

8. When possible, all data were taken from computer stored files. In some cases these data varied slightly from published reports.

Table A-4

Catalyst Removal Disablement Testing of Three-Way Catalyst Equipped Vehicles

Program*	Vehicle Number	Model Year	Manufacturer	Condition	FTP (gm/mi) HC	CO	NOx
OHIO	1	1981	GM	Ok	0.42	2.76	0.79
				Removed	2.88	14.08	2.59
OHIO	2	1981	Ford	Ok	0.54	10.55	0.63
				Removed	2.20	55.49	1.49
OHIO	4	1981	VW	Ok	0.35	2.01	0.98
				Removed	1.70	10.67	3.45
OHIO	5	1982	GM	Ok	0.13	2.09	0.43
				Removed	1.39	8.35	3.96
Averages				Ok	0.36	4.35	0.71
				Removed	2.04	22.15	2.87
			Average Excess		1.68	17.80	2.16

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*Programs listed in references.

Table A-5

Habitual Misfueling Testing of Oxidation Catalyst Vehicles

Program*	Vehicle Number	Model Year	Manufacturer	Condition	FTP (gm/mi)	
					HC	CO
STL	9401	1979	Ford	Ok	0.67	6.77
				Misfueled	3.20	21.70
STL	9402	1979	Ford	Ok	0.91	3.67
				Misfueled	3.04	13.00
STL	9403	1979	GM	Ok	0.54	3.57
				Misfueled	1.61	6.90
STL	9404	1979	GM	Ok	0.87	12.47
				Misfueled	2.06	15.30
Averages				Ok	0.75	6.62
				Misfueled	2.48	14.23
				Average Excess	1.73	7.61

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*Programs listed in references.

Excess Calculation:

((2.48/0.75)-1.0)* 1.07 = 2.47 gm/mi HC

((14.23/6.62)-1.0)* 18.23 = 20.96 gm/mi CO

This calculation increases the MOBILE3 estimate of zero-mile emissions for oxidation catalyst technology vehicles by the percentage increase in emissions due to habitual misfueling to give the excess emissions use in this report.

Table A-6

Habitual Misfueling Testing of Three-Way Catalyst Vehicles

Program*	Vehicle Number	Model Year	Manufacturer	Condition	FTP (gm/mi) HC	FTP (gm/mi) CO	FTP (gm/mi) NOx
FOSD	1	1982	GM	Ok	0.28	3.36	0.47
				Misfueled	2.81	23.64	1.02
FOSD	2	1982	Toyota	Ok	0.22	3.12	0.39
				Misfueled	1.70	11.76	1.78
FOSD	3	1983	Ford	Ok	0.24	3.60	0.61
				Misfueled	1.90	10.00	1.49
OHIO	1	1981	GM	Ok	0.42	2.76	0.79
				Misfueled	2.18	11.20	1.21
OHIO	2	1981	Ford	Ok	0.54	10.55	0.63
				Misfueled	2.14	39.64	0.82
OHIO	4	1981	VW	Ok	0.35	2.01	0.98
				Misfueled	1.40	2.24	1.98
OHIO	5	1982	GM	Ok	0.13	2.09	0.43
				Misfueled	1.05	8.12	1.27
Averages				Ok	0.31	3.93	0.61
				Misfueled	1.88	15.23	1.37
				Average Excess	1.57	11.30	0.76

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*Programs listed in references.

Table A-7

EGR Disablements Among Pre-1975 Model Year Non-Catalyst Vehicles

Vehicle Number*	Model Year	Manufacturer	FTP NOx (gm/mi) EGR Condition OK	FTP NOx (gm/mi) EGR Condition Disabled	FTP NOx (gm/mi) Excess
5030	1973	Ford	1.40	2.65	1.25
5032	1973	GM	1.86	3.03	1.17
		Average NOx	1.63	2.84	1.21

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*Both vehicles were repaired as part of Task 5 in Portland. See references.

Table A-8

EGR Disablements Among 1975-1976 Model Year Oxidation Catalyst Vehicles Built to a 3.1 gm/mi NOx Standard

					FTP NOx (gm/mi)		
					EGR Condition		
Site*	Vehicle Number	Model Year	Manufacturer	Test	OK	Disabled	Excess
Chicago	6004	1976	Chrysler	4/8	1.88	6.10	4.22
Chicago	6013	1976	Chrysler	3/7	2.93	4.42	1.49
Chicago	6014	1976	Chrysler	3/6	2.45	5.04	2.59
Chicago	5026	1975	Chrysler	4/7	2.98	4.77	1.79
Chicago	6033	1976	Chrysler	4/7	2.65	3.90	1.25
Chicago	6034	1976	Ford	4/6	2.93	4.25	1.32
Chicago	5035	1975	Ford	2/6	2.62	4.06	1.44
Chicago	6041	1976	Ford	1/6	2.16	5.20	3.04
Chicago	5047	1975	Ford	4/6	2.89	4.98	2.09
Chicago	6050	1976	Ford	4/6	3.34	7.21	3.87
Chicago	6059	1976	Ford	2/6	1.88	7.21	5.33
Chicago	6062	1976	Ford	4/9	2.79	8.11	5.32
Chicago	6068	1976	GM	1/8	2.62	7.45	4.83
Chicago	6071	1976	GM	2/8	3.09	7.62	4.53
Chicago	6081	1976	GM	1/8	2.43	4.87	2.44
Chicago	6083	1976	GM	1/8	2.42	3.71	1.29
Chicago	6094	1976	GM	2/8	2.67	2.64	-0.05
Chicago	6099	1976	GM	2/8	2.96	6.19	3.23
Wash., D.C.	6011	1976	Chrysler	4/9	2.94	10.99	8.05
Wash., D.C.	6029	1976	Chrysler	4/7	2.66	7.42	4.76
Wash., D.C.	6031	1976	Chrysler	4/6	3.01	5.07	2.06
Wash., D.C.	6049	1976	Ford	4/8	2.99	6.38	3.39
Wash., D.C.	6052	1976	Ford	4/6	1.82	7.10	5.28
Wash., D.C.	6060	1976	Ford	4/8	3.07	7.66	4.59
Wash., D.C.	6073	1976	GM	4/7	2.39	5.50	3.11
Wash., D.C.	6086	1976	GM	4/9	2.18	3.84	1.66
Wash., D.C.	6096	1976	GM	3/8	2.65	3.68	1.03
Detroit	6002	1976	Chrysler	3/6	2.95	9.82	6.87
Detroit	6021	1976	Chrysler	4/6	1.83	5.69	3.86
Detroit	6024	1976	Chrysler	2/6	3.09	4.09	1.00
Detroit	6025	1976	Chrysler	3/6	3.05	4.45	1.40
Detroit	6035	1976	Ford	1/7	2.20	4.30	2.10
Detroit	6040	1976	Ford	1/7	1.69	5.83	4.14
Detroit	6046	1976	Ford	4/7	1.71	6.43	4.72
Detroit	6064	1976	Ford	2/7	1.37	5.47	4.10
Detroit	6066	1976	Ford	1/7	2.07	6.72	4.65
Detroit	6083	1976	GM	1/7	1.91	2.85	0.94
Detroit	6090	1976	GM	1/7	2.16	7.68	5.52
Detroit	6091	1976	GM	2/7	2.03	7.75	5.72
			Average NOx		2.50	5.81	3.31

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*All vehicles deliberately disabled as part of the FY76 Restorative Maintenance Program. See References.

Table A-9

EGR Disablements Among Oxidation Catalyst Vehicles Built to a 2.0 gm/mi NOx Standard

Program*	Site	Vehicle Number	Model Year	Manufacturer	FTP NOx (gm/mi)		
					EGR Condition		
					OK	Disabled	Excess
DRIVE	NA	1	1977	GM	1.80	4.92	3.12
DRIVE	NA	2	1977	GM	2.72	3.71	0.99
DRIVE	NA	4	1978	GM	1.66	5.21	3.55
DRIVE	NA	5	1977	GM	1.66	4.94	3.28
DRIVE	NA	6	1978	GM	1.26	4.12	2.86
DRIVE	NA	7	1977	GM	1.67	5.11	3.44
DRIVE	NA	8	1977	GM	2.00	7.60	5.60
DRIVE	NA	9	1977	GM	2.56	8.30	5.74
DRIVE	NA	10	1977	Ford	1.45	4.14	2.69
DRIVE	NA	11	1977	Ford	1.45	7.68	6.23
DRIVE	NA	13	1977	Ford	2.03	7.15	5.12
DRIVE	NA	15	1977	Ford	2.42	8.42	6.00
DRIVE	NA	16	1977	Ford	1.80	6.34	4.54
DRIVE	NA	17	1977	Chrysler	1.43	2.65	1.22
DRIVE	NA	20	1978	AMC	1.11	4.23	3.12
RM76	SF	6003	1976	Chrysler	1.42	5.18	3.76
RM76	SF	6010	1976	Chrysler	1.41	4.22	2.81
RM76	SF	6012	1976	Chrysler	1.17	5.59	4.42
RM76	SF	6023	1976	Chrysler	1.59	4.54	2.95
RM76	SF	6036	1976	Ford	1.50	3.72	2.22
RM76	SF	6039	1976	Ford	2.02	5.48	3.46
RM76	SF	6065	1976	Ford	1.96	5.27	3.31
RM76	SF	6123	1976	Chrysler	1.53	3.58	2.05
REG	NA	10	1978	GM	1.26	3.54	2.28
REG	NA	12	1978	GM	1.20	1.79	0.59
REG	NA	15	1978	Ford	1.61	6.68	5.07
				Average NOx	1.68	5.16	3.48

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*See References.

Table A-10

EGR Disablements Among Three-Way Catalyst Vehicles Built to a 1.0 gm/mi NOx Standard

					FTP NOx (gm/mi)		
					EGR Condition		
Program*	Site	Vehicle Number	Model Year	Manufacturer	OK	Disabled	Excess
FY80	LA	344	1981	GM	0.37	1.68	1.31
FY80	SA	19	1981	GM	0.63	1.19	0.56
FY81	SA	617	1981	VW	2.45	3.27	0.82
FY82	ARB	8197	1981	Ford	1.37	2.38	1.01
FY82	ARB	8314	1981	GM	1.06	2.81	1.75
CL82**	ARB	705	1981	Ford	0.88	1.92	1.04
MVEL**	ARB	-	1982	GM	0.62	2.74	2.12
				Average NOx	1.05	2.28	1.23

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*See references.
**Deliberate disablements.

Table A-11

Oxygen Sensor Disablement Testing

Program*	Vehicle Number	Model Year	Manufacturer	Condition	FTP (gm/mi) HC	FTP (gm/mi) CO	FTP (gm/mi) NOx
CL82	701	1981	AMC	Ok	0.25	2.05	0.96
				Disabled	0.27	2.57	0.88
CL82	702	1981	Chrysler	Ok	0.24	1.72	1.12
				Disabled	0.25	3.28	0.64
CL82	703	1981	Chrysler	Ok	0.50	9.21	0.80
				Disabled	0.87	32.90	0.31
CL82	704	1981	Ford	Ok	0.63	6.58	1.24
				Disabled	0.74	9.95	0.41
CL82	705	1981	Ford	Ok	0.30	3.40	0.88
				Disabled	0.27	3.71	1.26
CL82	707	1982	GM	Ok	0.09	1.35	0.50
				Disabled	1.58	59.71	0.39
CL82	708	1982	GM	Ok	0.15	3.56	0.54
				Disabled**	3.19	157.66	0.22
CL82	711	1981	Ford	Ok	0.31	2.00	0.89
				Disabled	0.25	1.62	1.59
CL82	713	1981	VW	Ok	0.11	1.38	0.32
				Disabled	2.41	109.59	0.07
CL82	714	1981	Toyota	Ok	0.10	0.96	0.58
				Disabled	1.68	32.90	0.20
CL82	715	1982	GM	Ok	0.14	4.03	0.37
				Disabled**	4.17	175.08	0.11
CL82	716	1981	Chrysler	Ok	0.72	9.73	1.00
				Disabled	1.52	31.25	0.37

Table A-11 (cont'd)

Oxygen Sensor Disablement Testing

Program*	Vehicle Number	Model Year	Manufacturer	Condition	FTP (gm/mi) HC	FTP (gm/mi) CO	FTP (gm/mi) NOx
CL82	718	1981	Ford	Ok	0.97	8.12	0.67
				Disabled	1.00	14.67	0.45
CL82	720	1981	GM	Ok	0.40	1.34	0.99
				Disabled	0.31	1.46	3.02
CL82	721	1981	GM	Ok	0.26	2.74	0.79
				Disabled	0.31	2.88	1.83
CL82	722	1981	VW	Ok	0.33	5.17	1.30
				Disabled**	10.70	186.06	0.11
MVEL	-	1982	GM	Ok	0.13	1.85	0.62
				Disabled	0.42	11.63	0.46
MVEL	-	1982	GM	Ok	0.13	1.85	0.62
				Disabled**	4.83	171.99	0.29
FOSD	1	1982	GM	Ok	0.28	3.36	0.47
				Disabled	0.24	2.19	1.82
FOSD	2	1982	Toyota	Ok	0.21	2.29	0.37
				Disabled	0.33	7.09	0.75
FOSD	3	1983	Ford***	Ok	0.24	3.60	0.61
				Disabled	0.23	4.70	0.51
Averages				Ok	0.31	3.63	0.74
				Disabled	1.69	48.71	0.75
				Average Excess	1.38	45.08	0.01

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* Programs listed in references.

** Oxygen Sensor grounded.

***Light-Duty Truck.

Table A-12

Evaporative Control System Disablement Testing

Model Year	Manufacturer	Model	Condition	Evaporative HC Diurnal (gm/day)	Evaporative HC Hot Soak (gm/trip)
1981	GM	Cutlass	Ok	0.67	0.97
			Disabled	18.81	7.34
1981	GM	Malibu	Ok	2.24	12.70
			Disabled	19.51	12.73
		Average	Disabled	19.16	10.04

Trips per day = 3.05
Miles per day = 31.10

((3.05 * 10.04) + 19.16)/31.10 = 1.60 gm/mi.

Appendix References

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